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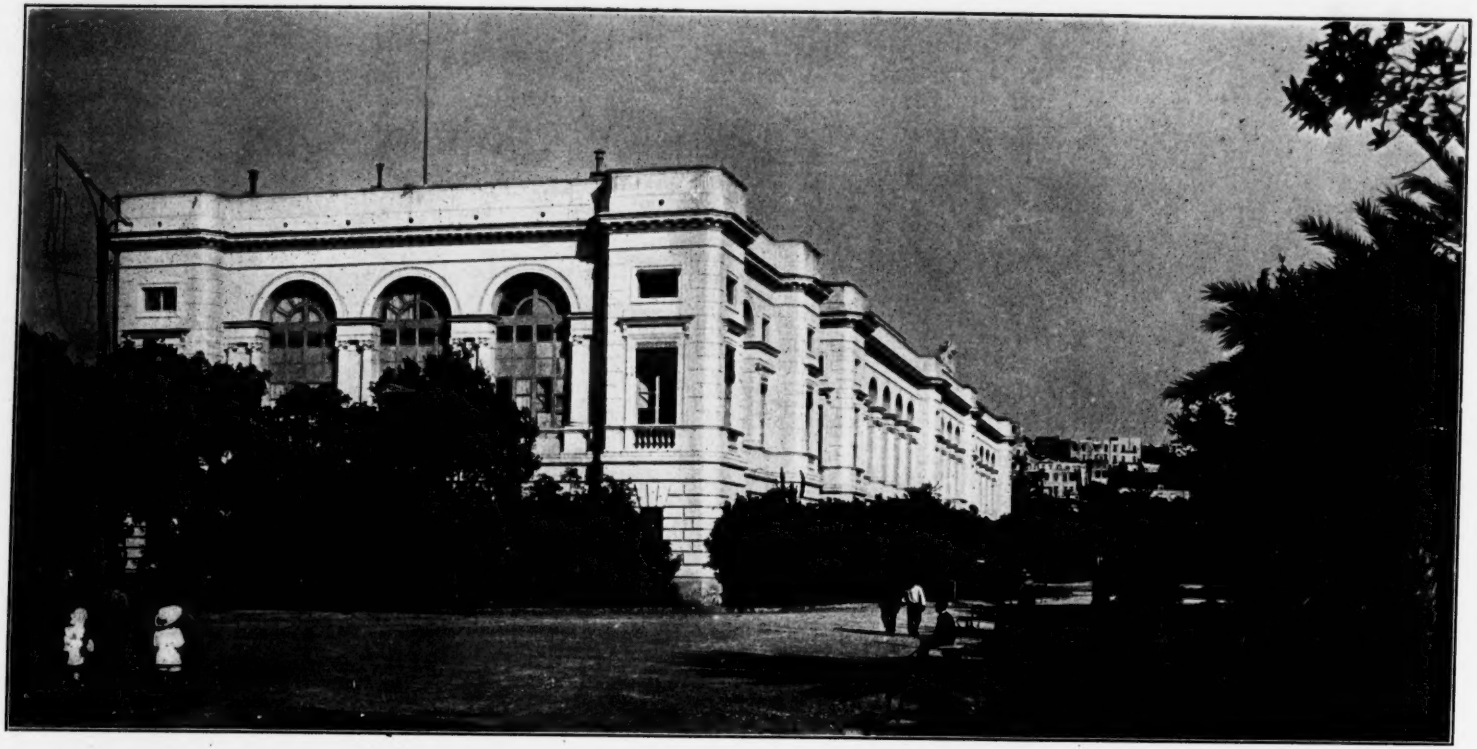
THE ZOOLOGICAL STATION AT NAPLES

By Professor CHARLES LINCOLN EDWARDS

TWENTY centuries ago the rain of ashes and pumice-stone from Vesuvius buried Pompeii, and, at the same time, a stream of mud sealed up Herculaneum. Within the period of the last three hundred years, four times in succession, Torre del Greco has been covered by the flowing lava, but each time this town has been rebuilt. The great lava-stream of the eruption of 1906, lying just beyond Torre Annunziata, is an ominous demonstration of the evil possibilities still within old Vesuvius. To-day the small white cloud of smoke above the summit of the volcanic ash-cone merely hints of these latent forces that may again overwhelm some community at the base, while now the great mountain rests in its beauty and historic interest, overlooking the blue waters of the Bay of Naples. To the right are the massive buildings of the city intersected by narrow passage-ways, all crowded between the shore and the high wall of the hills which stretch from the Pallazzo Capodimonte to the Posilipo. Far away at either side of the Bocca Grande are the islands of Capri and Ischia, at times clearly outlined, or again almost lost in the haze of opalescent mist.

All through the day many groups of fishing-boats are scattered about the bay while the men cast and haul their nets. Over the stone sea-wall others pull on the end-ropes of a drag-net that has been set far from shore, until at last the great burden of fish is safely unmeshed. Here and there divers go down to scrape the rocks and sand of the bottom for mussels which are placed in a bag worn at the waist. From an anchored skiff a man dredges with a scoop-net attached to a long pole contented with many of the living things that appear, for strange creatures are welcome in the Neapolitan market. Thus, without planting or cultivating, the people gather from the sea an unending harvest. But from under the cliff of Sorento, to the wave-eroded rocks of Ischia,

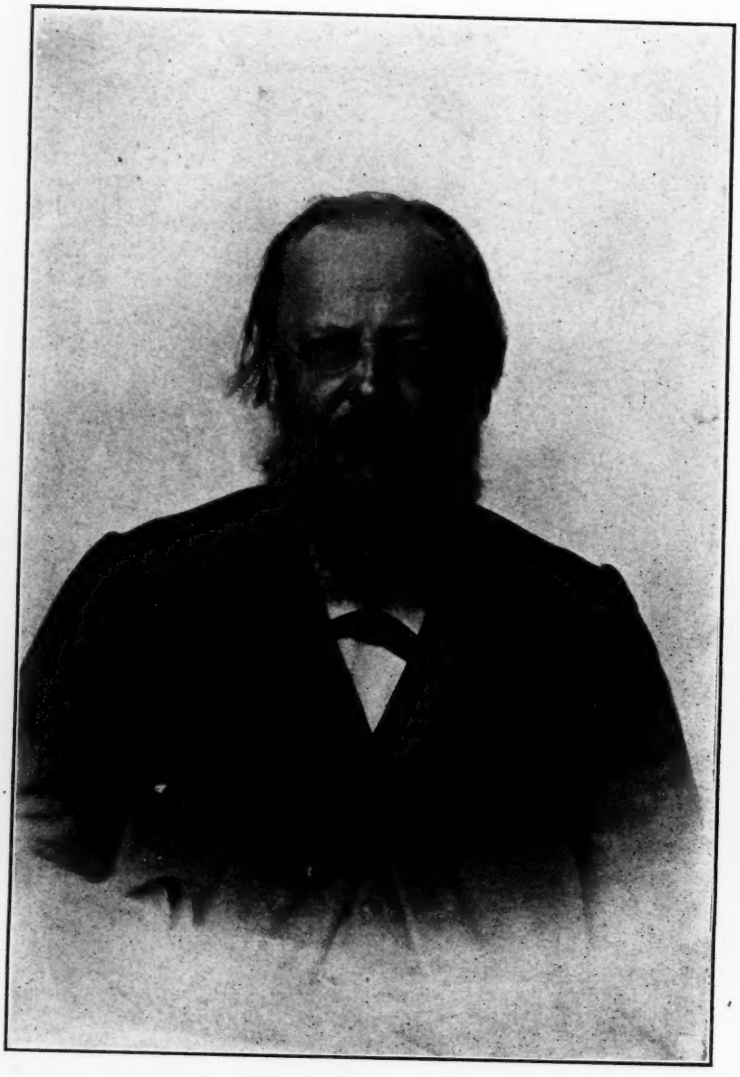


VIEW OF THE ZOOLOGICAL STATION FROM THE WEST.

whenever a fisherman finds a strange or curious creature he carefully brings it to the zoological station, sure of ready purchase in an institution that uses every agency for the advancement of the knowledge of the life of the sea.

The opening of the zoological station in 1874, realized the dream of Anton Dohrn of a laboratory for marine biological investigation, and now, in the high development of this institution, we mourn the death of its creator, which occurred on the twenty-sixth of September, 1909. Dohrn himself tells in an article in the *Preuszische Jahrbücher* for 1872, how, during his travels to various European coasts, the necessity was impressed upon him for the erection of marine laboratories suitably equipped for research. In October, 1868, after a journey to Scotland rendered disappointing by bad weather, Dohrn sought the rich faunal region of lower Italy and Sicily where Johannes Müller and his students had been pioneers in marine zoology. Fully realizing that such an institution as he planned does not spring into being completely formed by *generatio æquivoca,* but rather develops like an organism, Dohrn began to collect money for the erection in Messina of a building which should contain rooms for investigation and also an aquarium for the entertainment of the public. The next step, in January, 1870, was to change the plan so as to locate in Naples where the larger numbers of tourists and citizens would justify a great aquarium, not only for popular education but as a substantial aid in support of the scientific work of the institution. In the *Deutsche Rundschau* for 1892, Dohrn tells the story of the preliminary work necessary to enlist the interest and support of the Prussian ministry and the government of Naples. Overcoming difficulties and interferences that would have utterly discouraged a less enthusiastic and steadfast nature and valiantly taking his patriotic part in the Franco-Prussian war, it was not until June, 1872, that a contract with the city authorities was executed for the erection by Dr. Dohrn of a building for the zoological station. The original contract has since been modified, so that now the station occupies 4,000 square meters of ground in the Villa Nazionale and is to remain in the possession of the Dohrn family for ninety years, then reverting to the city of Naples, unless otherwise provided for.

While devoting his own life and his estate to the building up of a great central station for marine biology in Naples, Dohrn urged the necessity for similar stations in all lands, to release investigators from the troubles and expenses otherwise involved. These advantages he especially desired for the young men fresh from the university, who might thus increase their powers, widen their knowledge and enlarge their general point of view. If it be possible to remain free from the pressing necessities of life for four or five years, such a young man could demonstrate whether he really had the call to be an investigator. The work would necessitate the wearisome uncovering of the smallest



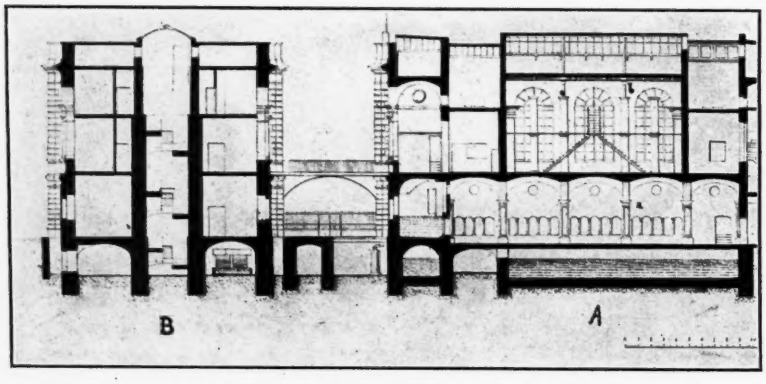
Yrs. tr. Anton Dohrn

facts, together with the placing of large problems before the mind for imagination and criticism to solve. An enthusiast for Darwinism and influenced by the philosophical writings of Leuckart and Milne-Edwards, from the very beginning, Dohrn's conception of the field of work broadly included the investigation of function as well as form, and the phylogeny of both. The dissection of animals, the study of their tissues by the aid of the microscope and the description of their life histories from the fertilized egg through all the changing embryonic and larval stages, should be reinforced by physiological experiment and chemical analysis, together with the observation of the manner of living and behavior of the animals.

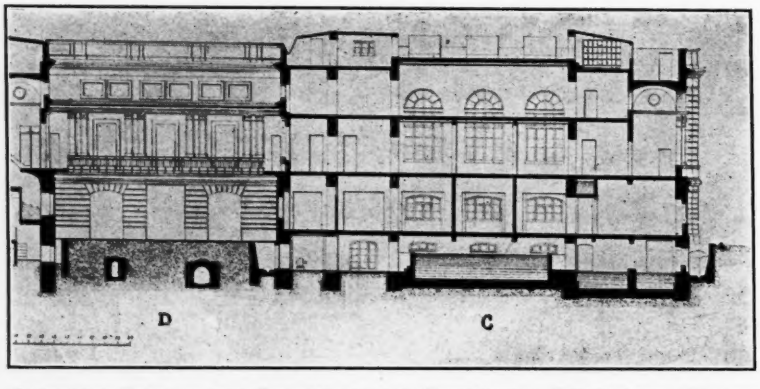
The zoological station is situated on the shore of the bay in the Villa Nazionale, on the most beautiful and convenient site in Naples. One approaches by a long walk flanked by rows of stone-oaks whose overarching, intertwining branches produce a grateful shade from the brilliant sunshine. Here and there groups of phœnix palms, spreading, leafy palmettos and cycads, add the appropriate subtropical vegetation. The renaissance architecture is perfectly adapted to the uses of the station, while the beautiful structure fits into the scene as naturally as the palms themselves.

The oldest of the three buildings (*A*) of the zoological station was opened in 1874 and is now chiefly occupied by the public aquarium (*a*) and the library (*b*). The second building (*B*), finished in 1886, is connected to the western end of the first by bridges and contains the department for collecting and preserving organisms as well as individual laboratories for zoologists. The third addition (*C*) was built in 1906 for the new science of comparative physiology. This laboratory lies to the east of the aquarium, being connected therewith by a building (*D*) surrounding a court. It is scarcely necessary to enumerate the rooms and describe them in detail. In fact no one at the station could tell me just how many rooms there are! It is sufficient that each investigator is provided with a laboratory containing large and small aquaria, tables, and all necessary reagents and apparatus for his work. There are also large general laboratories for zoology, physiology, botany and chemistry, with all the equipment necessary for research. The museum, now under charge of Dr. Gast, contains a faunal series of specimens so wonderfully preserved that often they are more beautifully expanded than the living animals themselves.

From the brilliant sunlight one enters the semi-obscurity of the large aquarium hall. Great tanks, with plate-glass fronts, are around the sides of the room, and a double row in the middle partially divides the hall. The only light enters through the water, so that one has the impression of being in a submarine environment. The sea-water is stored in large tanks upon the upper floor, then, mixed with air, circu-



SECTIONAL PLAN OF THE FIRST TWO BUILDINGS OF THE ZOOLOGICAL STATION. *A*, building containing (*a*) aquarium and (*b*) library; *B*, individual laboratories.



SECTIONAL PLAN OF THE LABORATORY FOR COMPARATIVE PHYSIOLOGY (*C*) AND CONNECTING BUILDING AROUND THE COURT.

lates through the aquaria and finally runs into a sand-filter in the basement to be again pumped into the upper tanks. Every fourteen days a fresh supply is pumped in from the sea. A perfectly developed system of collecting enables the institution to exhibit the most beautiful and interesting animals of the bay of Naples in large numbers and in the best condition. A little book published in Italian, German, French and English gives, in simple language, just such a description of the animals, their habitat and behavior, as will appeal to the public. There are many "happy families" formed upon long observation of the different kinds of animals that may live together without acquiring too marked a taste for one another. The aquarium containing the coral animals is constructed like a grotto under the arch of which one sees the orange-colored polyps spread about like marigolds. Some of the related anemones are actually old, as is shown by their long, wrinkled, thick-skinned bodies, but their straight, or slightly curled tentacles of purple, or lavender, or cream-color, or brown, are most beautiful.

Among the echinoderms the methods of feeding are interesting. The sea-cucumber holds fast to a rock by means of the suckers at the tips of its tube-feet, and, with tentacles widely expanded like the branches of a tree, waits for minute crustaceans and the larvæ of all sorts of animals to comfortably settle themselves upon the hospitable branches. Then, with the least possible motion, the sea-cucumber very gradually bends a tentacle over and into the mouth, and, as it is again extended one of the two small tentacles scrapes off the resting organisms. So each tentacle, in rhythmical succession, takes its turn in the feeding process. Some species of star-fishes have large mouths and can swallow snails and mussels whole, sometimes consuming as many as twenty-five or thirty mollusks of various kinds at one meal. Other star-fishes have mouths too small to receive the animals commensurate with their appetites and so they simply turn their stomachs inside out, covering over a clump of oysters, and thus forming a sort of external stomach into which the secretion from the digestive glands is poured. When the soft parts are thus dissolved and absorbed the star-fish pulls in its stomach and goes on in its devastating course. The sea-urchin has an apparatus known as Aristotle's lantern providing five strong teeth worked by powerful muscles with which it catches live worms and crabs. The sea-crawfishes, built like lobsters except for the absence of the large pincers, most perfectly convey the impression of life on the bottom of the sea. They seem like uncanny agents of evil as they solemnly stalk about over the rocks, poking their great antennae into each other's affairs and always having several claws out for a fight, yet seldom engaging with one another. Some of the veterans, however, have lost an antenna, or a leg, and the missing parts are being regen-

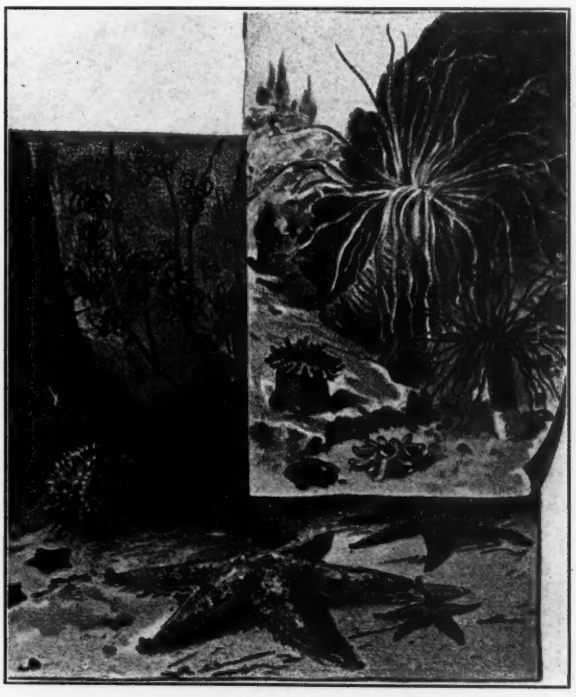
THE PALM-LIKE RINGED WORMS.

ONE OF THE HAPPY FAMILIES IN THE AQUARIUM.

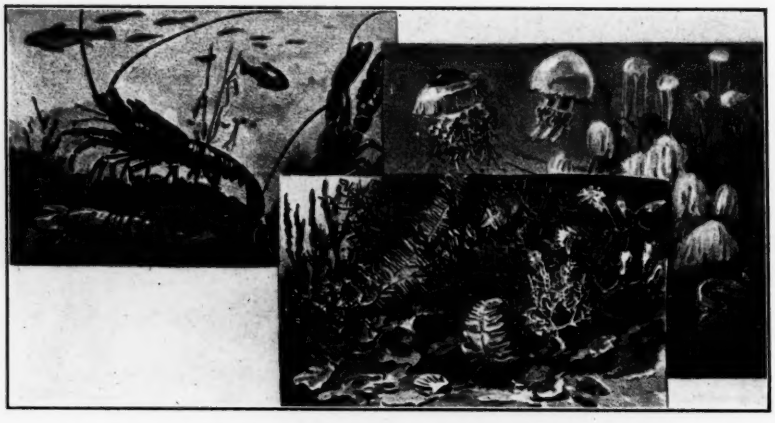
erated. The semi-transparent squids, with posterior triangular fins, swim back and forth as delicately poised as submarine monoplanes. When a live fish is placed in the water the squid darts at it, grasps it firmly with the suckers or the tentacles and cuts off the head, eating only the body. The cuttlefish, with broader body, striped like a zebra, and big elephantine head, constantly undulates a fin-like fringe around the border of its mantle, as it nervously drifts here and there. Frequently it wriggles into the sand which it throws upon its back, or, if much disturbed, ejects a cloud of ink in which it disappears. The large octopus has a body that suggests both a toad and a spider, with highly developed eyes and brain projecting above it. Generally this devil-fish lies sleeping in a corner of the rocks, or lazily reaching out and creeping about by means of eight long tentacles that express a giant's strength. With a spurt of water from its siphon the octopus may dart rapidly through the tank, and by directing the tube of its siphon, go whither it wills. Lying upon the bottom of an open trough, often buried in the sand, is the very interesting electric ray. If one presses the fingers upon the broad body where it runs into the tail he will, in the words of a Cook's guide, "get a strike." The electric tissues are descended from muscle fibers which in the course of evolution have come to produce electricity instead of motion. In the embryo ray the primitive muscle cells first appear, then they swell out anteriorly and shrivel up posteriorly until each loses the characteristic striated muscle structure and becomes an electric plate lying in a little compartment embedded in a jelly-like substance. Electricity is produced by some chemical action upon innumerable minute granules stored up in the protoplasmic network pervading the electric plates. The shock

is brought about by the stimulation of the electric nerve, which in turn acts upon very minute electric rods that release the electricity.

Above the aquarium is the library. In the north room are found in complete series all the most important biological journals. In the south room are the separate volumes, monographs and authors' reprints. The current numbers of journals and the latest publications from all parts of the world are found upon central tables. The classification and arrangement of the books is simple and the card-catalogue complete. Each worker is given cards bearing his special number in the general list and he inserts one of these cards in the place of the book desired. Dr. Schoebel, the librarian, is always ready with assistance in case of need. On the walls are notable frescoes by Hans v. Marées, one of the group of four especial friends of Dohrn when, in 1871, he was Privatdozent at the University of Jena. In the fresco on the east wall, Dohrn and these four friends, the biologist Kleinenberg, Charles Grant, the author of "Tales of Naples and the Camorra," the artist himself and the sculptor Hildebrand, are represented as grouped about a table at the ruins of the Palazzo di Donn' Anna on the Posilipo. In two other scenes, first Neapolitan fishermen are carrying the net from the shore and launching their boat and then four stalwart fishermen are rowing, standing in their characteristic manner and bending forward with each push upon the oar. On the south wall three ages of man are repre-



ECHINODERMS AND ANEMONES.



SEA-CRAWFISH AND OTHER CRUSTACEANS, MEDUSÆ AND CORALLINE ANIMALS.

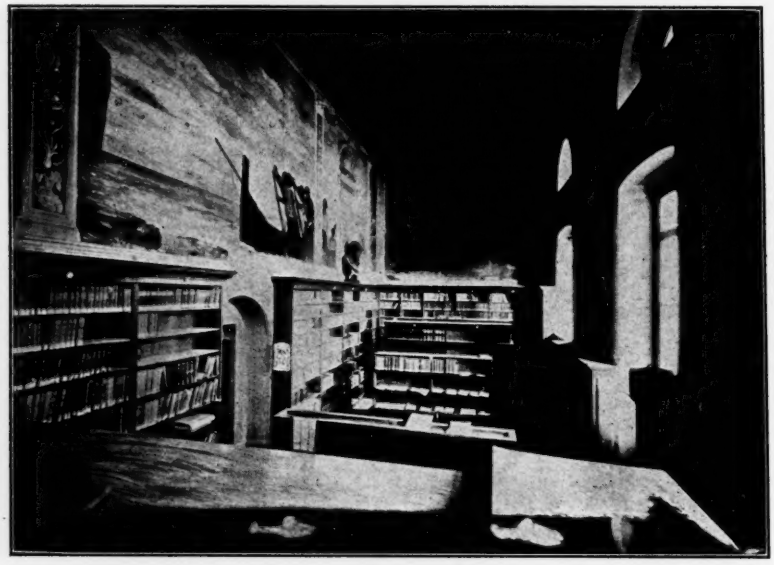
sented in an orange grove; the child lying on the sand and playing, the man in his prime gathering the ripe fruit and the old man bending over his spade. The ornamental panels between the frescoes and the frieze, as well as impressive busts of Darwin and Von Baer, are by Hildebrand.

Three very important publications are issued by the zoological station under the able editorship of Professors Dr. P. Mayer and Dr. Giesbrecht. The *Fauna und Flora des Golfes von Neapel* consists of a series of more than thirty splendid monographs upon the animals and plants of the bay. Following the ideal sketched by Dohrn in 1880 as a foreword to the first volume, each monograph embodies the anatomy, histology, embryology and physiology, as well as the taxonomy, of the animals or plants of the group treated. Beginning with Chun's great work on the ctenophores, these monographs are models of a systematic zoology and botany based upon the whole range of biological science. They are beautifully illustrated by the authors themselves, often assisted by the talented artists of the station, Merculiano, Serino and Manzoni. The *Mittheilungen aus der Zoologischen Station zu Neapel,* now in its nineteenth volume, is a journal for the publication of shorter papers and contains the earlier annual reports of the director. The annual *Jahresberichte* contain admirable analyses of all the zoological literature of the year. While these publications contain many most important contributions, yet far beyond the limits of the station, almost every biological journal receives papers based upon investigations carried on, in whole or in part, in Naples, or upon material furnished by the institution.

For the purpose of meeting current expenses, in addition to the receipts from visitors to the aquarium, Dohrn conceived and developed the "table" plan by means of which various governments, universities

or associations may rent tables at which naturalists may work. By this means the station assumed an international character and remained free from governmental control, to develop under the wise direction and tireless energy of its founder, unimpeded by bureaucratic interference or the cumbersome machinery of a commission. At the cost of $500 a year a table may be taken and allotted to investigators in succession for the longer or shorter periods desired. All the resources of the institution are thus available to such an occupant without cost to himself. At present fifty tables are under contract. Germany has twenty-two tables, of which eleven are provided for by an imperial grant of twenty thousand Marks, while, in addition, Prussia has four and Bavaria, Saxony, Württemburg, Baden, Hessen, Hamburg and the University of Strassburg, one each. Italy has twelve tables, Russia four, Austria two, Hungary, Holland, Belgium, Switzerland and the Roumanian Academy, each one. In England the universities of Oxford

SQUIDS AND OCTOPI,
ROMAN AND CONGER EELS.



VIEW OF LIBRARY, LOOKING EAST.

and Cambridge and the British Association for the Advancement of Science have each a table. In the United States, the Smithsonian Institution has one, the Carnegie Institution two, Columbia University and the Association for Maintaining the American Woman's Table at the Zoological Station in Naples, one each.

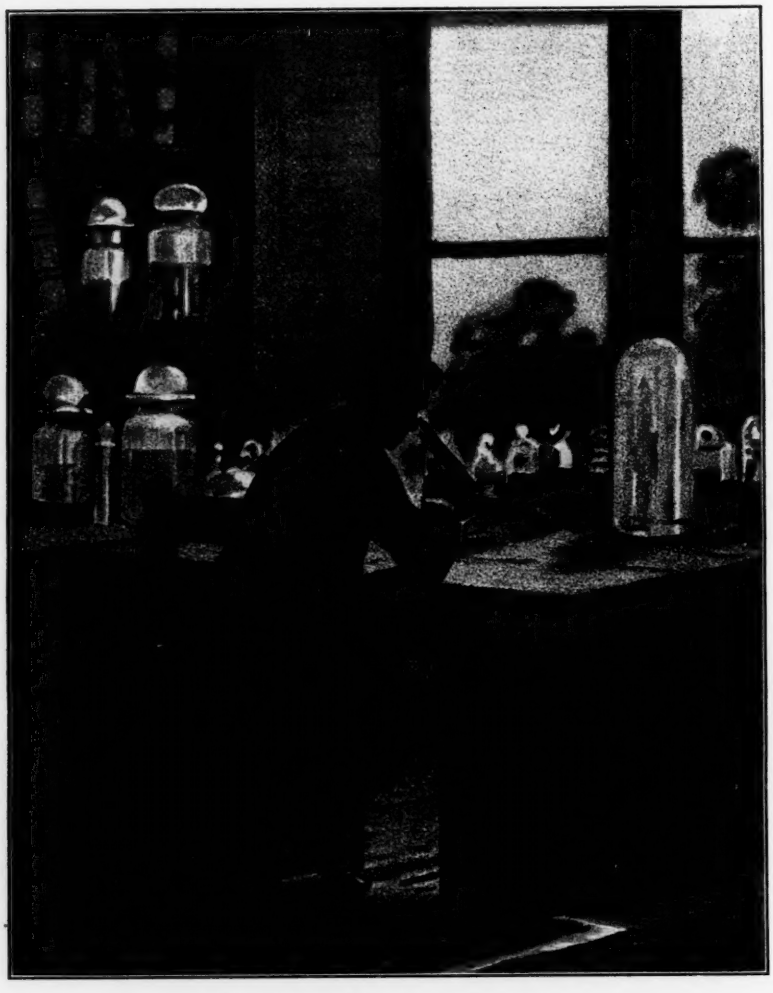
For the erection of the new laboratory of comparative physiology citizens of Germany have given 300,000 Marks, and with also at present an annual payment of 20,000 Marks, this country has shown implicit faith in Dohrn and his work. Of the 2,000 workers up to 1910, more than one half have been Germans. Besides supporting her tables, Italy has contributed 100,000 francs to the second building, and for over thirty years has given 5,000 francs annually to the library. During the thirty-six years since the founding of the station biological research has been awakened in Italy, until now her workers stand in the foremost ranks. In the early stages of the station English naturalists, headed by Darwin, gave £1,000 and thus assured Dohrn of international sympathy and support in his splendid work.

Dohrn, as owner and chief of the station, established the most complete system for the transaction of its business so that he always maintained the utmost confidence of the contributing governments and institutions. By the death of the founder, the directorship of the zoological station has descended to Dr. Reinhard Dohrn. That this great trust will be faithfully executed in the spirit of the founder's high ideals and will continue its remarkable development is evident to any one who knows Dr. Reinhard Dohrn. Each department is under

the direction of a member of the scientific staff, who is at the same time devoting his life to research in his own special field of natural history. At present the staff is organized as follows: Professor Dr. Mayer and Dr. Gross, morphology; Dr. Burian, comparative physiology; Dr. Henze, chemistry; Dr. Gast, the museum. One of the founder's first associates, Professor Dr. Eisig, now enjoying the benefit of the station's pension system, is still pursuing his life-work upon the annelids. The veteran secretary, Hermann Linden, assists in looking after the voluminous correspondence, and the local business with the city authorities, the railway, post and customs. A trained engineer and assisting machinists care for the electric motors, steam-engines, pumps and complicated network of gas, salt- and fresh-water pipes. In an especially equipped workshop a trained mechanic makes the instruments for experimental investigations. Dr. Lo Bianco developed beyond rivalry the department for the supply of animals and plants, either living for exhibition in the aquarium, or for the many workers in the various laboratories, or as perfectly preserved specimens for museums and investigators all over the world. Since the recent death of Dr. Lo Bianco his former assistant Sig. Santorelli has taken charge of this department. For collecting there is a fleet of well-manned boats, including the steamers *Johannes Müller* and *Francis Balfour* supplied with steam winding-reel for the dredges and trawls, and all sorts of nets and other necessary apparatus.

In 1885 Dohrn elaborated a plan of a floating laboratory for the extension of the work in marine biology. For this purpose a war-ship is too expensive to maintain and too ill adapted to the needs of investigation besides generally involving political and other interests distracting to biological research. An ordinary steamship would not be much better, so Dohrn planned a specially constructed and well-equipped

VIEW OF THE LIBRARY, LOOKING WEST.



THE LABORATORY OF AN INVESTIGATOR.

steamer of 300–400 tons of burden with an engine of from 150–200 horse-power and room for from six to ten investigators. Two laboratories, one above and the other below deck, completely outfitted for a six months' voyage together with a library would furnish ideal conditions for work. With such a floating biological station unknown regions could be entered with all the resources of modern equipment for both morphological and physiological work and investigations thus carried on which would not be possible upon land. To accomplish these results most economically the floating laboratory would be used, at first at least, in conjunction with the Naples Station, for the exploration of the bay of Naples, and the neighboring waters of the bays of Salerno and Gaeta. During the day-time the great depths would

be searched with dredge and trawl and fished with long lines, each bearing many baited hooks, and the pelagic animals caught from the side of the vessel. Small boats would be sent out to gather from the rocks and grottoes under the water-line such organisms as the sponges, corals, worms, echinoderms, mollusks and algae. A portion of the catch would be examined by the naturalists on board, another part kept in well aerated aquaria to be taken in the early morning by the *Johannes Müller* to the Naples Station. In the night-time silk townets would collect from the vast numbers of minute living things that then reappear after having gone below the surface waters to escape the intense sunlight. Stone-plates could be lowered to the sea-bottom in various places to be taken up and examined at regular intervals in order to study the assembling and growth of the sessile organisms that seek such locations. Then these stone-plates might be changed from one place to another, varying the depth, light and other conditions of existence in accord with the method of experimental zoology, with results of the greatest value to the knowledge of the distribution and evolution of marine organisms and scarcely possible except by means of such a floating laboratory. After exploring the sea around Naples the floating laboratory might be taken to the coasts of Sardinia, Tunis, Crete, Cyprus and other regions. The moment anchor is cast the vessel serves as dwelling house and laboratory from which would center all the activities of a marine station. If needed, a portable house, carried on board, could be quickly placed upon any desired shore. In connection with biology other kinds of scientific work such as geology, paleontology and philology might be advanced, with the best possible conservation of all the collections on board the ship, whereas it is often so difficult and dangerous to transport such things from isolated regions by the ordinarily available means. It is easily seen that such a combination would greatly advance the various sciences concerned at the least cost to each. This plan, always in Dohrn's mind, was temporarily laid in the background by the more pressing need of the erection of the building for comparative physiology which absorbed much time in the last years of Dohrn's life. Through the death of F. A. Krupp his promise to build a 700–ton yacht for this deep sea investigation came to naught. Now, although the Prince of Monaco is devoting much time and money to the development of oceanography, and various governments are sending out vessels, yet the field is so large and so important that it is to be hoped Dohrn's plan will be carried out not alone at Naples, but in America and other countries.

In spite of the time consumed in directing the affairs of the zoological station and in traveling and making addresses in its behalf, Dohrn was always an investigator of the foremost rank. During the half-century of continuous production his bibliography numbers eighty titles. Following in the footsteps of his father, the entomologist Karl

August Dohrn, his first two papers, published in his eighteenth year, were upon Hemiptera. Until 1881 his work was mostly concerned with the insects and other arthropods including his monograph on the Pantopoda for the *Fauna and Flora of the Bay of Naples.* However, as early as 1876, appeared the first of Dohrn's brilliant and suggestive papers on the origin of the vertebrates. Working upon the basis of embryological studies in such forms as the Ascidians, Amphioxus, the

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Cyclostomes, sharks, bony-fishes, and other vertebrates, Dohrn traced the phylogeny of the vertebrates to the annelid worms. Beyond their theoretical bearing upon a question still debatable, his discoveries constitute substantial additions to comparative anatomy and embryology.

The investigators at the station find intellectual and esthetic enjoyment in historic Naples and its neighborhood. Among the marbles and bronzes of the National Museum one finds such masterpieces as the Hera Farnese and the Narcissus. In Pompeii the uncovered auditorium and the uncurtained stage of the great theater seem to voice the awful tragedy of 79 in spite of the roses and larkspurs blooming

again in the peristyle of the house of the Vettii. In the present excavations one sees the volcanic debris removed from an atrium wall revealing in its pristine freshness a fresco of the brief period of reconstruction after the earthquake of 63. After the excursions from Naples certain pictures will always linger in the mind. The wonderful panorama from the Camaldulensian monastery extending from the Ponza Islands in the west to Monte Sant' Angelo in the southeast, and embracing the City of Naples with omnipresent Vesuvius in the background, and the islands of Nisida, Procida, Ischia and Capri. The view from the rose-garden of the Palazzo Rufolo, at Ravello, on the heights of Monti Lattari, with the fishing-boats of the bay of Salerno like winged creatures suspended just above the waves and gliding back to the gods who sent them forth. The temple of Neptune at Paestum, having withstood the devastation of wind and storm for twenty-five centuries, rising from the green meadows, with its massive yet graceful fluted Doric columns, sepia tinted by age, outlined against the blue sky and bluer sea. The blue grotto of Capri entered by a hole in the cliff so small that our little skiff scraped the rock, lighted by the sunshine which permeates the water from the one opening, and transformed into a great hall of fairyland with an atmosphere of silvery greenish-blue so clear that the primeval rock of the vaulted cavern is reflected in the shimmering depths below. The naturalists from many countries, all representing different phases of biological work and thought, create a cosmopolitan atmosphere most profitable and inspiring to each investigator. During the year ending March, 1910, there were 163 workers at the zoological station. Thus there is a perpetually changing and yet permanent congress wherein the exchange of ideas is not by means of formal lectures but rather in the conversation of two or three workers in some nook about the buildings, or upon the deck of the *Johannes Müller*. For the thirty-six years of its existence the Naples Zoological Station has been one of the most potent factors in the development of modern biology, and now this institution world-wide in its influence, stands as the chief monument to the remarkable personality of Anton Dohrn.

A UNIQUE COLLECTION OF ARITHMETICS

By Dr. LOUIS C. KARPINSKI
UNIVERSITY OF MICHIGAN

RECENT visitors to the Metropolitan Museum of Art have been impressed by the wealth of the loan collections standing in names comparatively unknown to the general public. A two-million-dollar sale of works of art lately excited only passing comment—in spite of the fact that many priceless treasures were forever lost to America. The existence of this private gallery was made widely known only through the dispersal of its paintings—and the unfortunate story of its loss to New York City. There are many other storehouses of those things which we human beings prize in this great city. Fortunately not all of them need to be destroyed as collections before their significance and charm receive adequate recognition. So the Morgan library in its own somewhat permanent home is now numbered among the city's choicest possessions.

The existence in the metropolis of an absolutely unrivaled collection of fifteenth and sixteenth century arithmetics has been brought to the attention of the scientific world by the publication of David Eugene Smith's "Rara Arithmetica." While the work purports to be a mere descriptive catalogue of the arithmetical books of the period mentioned which are in the library of G. A. Plimpton, it is in fact a comparatively complete bibliography of the subject, since this library contains practically all the arithmetic books published in the first hundred and fifty years of printing. As the third, and by far the most complete, collection of arithmetical works of international fame the Plimpton books take a high place among modern private libraries.

George A. Plimpton's interest in arithmetics grew out of his business as a publisher of text-books. The historical development of the school curriculum is exhibited by his library. Included are geographies from the invention of printing up to modern times, spellers, writing books with wonderful specimens of writing from all the world, geometries, reading books and representatives of the other subjects of the ordinary school program. But the gems of the collection are doubtless the mathematical works, for in these Mr. Plimpton's interest has been stimulated by Professor David Eugene Smith, himself an enthusiastic bibliophile. The bookshops of all the world have yielded their treasures to these indefatigable searchers. Professor Smith's recent trip

around the world brought mathematical finds to the Plimpton and Smith collections in the shape of Arabic and Persian, Hindu and Chinese and Japanese manuscripts and rolls.

Mention should also be made of the medallions of mathematicians, on exhibition in Teachers College, extending back nearly to the time of Pythagoras. The Smith collection of portraits of the devotees of numbers is without parallel and the autograph letters and documents are priceless. Here is an original note-book from the hand of Newton, and the more prosaic receipt for his semi-annual annuity of fifty pounds granted by parliament. The diploma of the great physiologist E. H. Weber, signed by Carl Friedrich Gauss, probably the greatest mathematician of all time, will interest especially those who are familiar with the labors of these men.

The invention of printing gave a tremendous stimulus to all scientific work by making possible the wide diffusion of knowledge, as well as by facilitating the intercourse of scholars. A potent indication of the really scientific spirit of the learned men of that day is the fact that the newly discovered art was used to give the older classics a wider circulation. Thus it need not surprise us to find in this bibliography of the fifteenth and sixteenth centuries the names of the more ancient writers.

Archimedes (287–212 B.C.), whom we ordinarily recall as a geometer tracing figures in the sand and incidentally being killed while engaged in this harmless occupation, or as a master of applied mechanics defending Syracuse with his catapults and burning glasses, appears in the "Rara Arithmetica" as the author of a work on numeration. Archimedes explains how it is possible to obtain numbers sufficient to express the grains of sand in a sand-heap as large as the world and even as large as the universe, a problem which is also found in India.

The arithmetic of Boethius (c. 480–524) involving that of Nicomachus of Gerasa (fl. c. A.D. 100) was the most widely used text-book in the monastic schools of the middle ages. Doubtless never again will any text-book be kept in use for approximately a thousand years, and yet an examination of the content of this text reveals not science, but hair-splitting philosophical discussions and extreme poverty of ideas. Boethius might have been expected to be a more practical philosopher, for he wrote his "Consolations of Philosophy" while he was in prison.

The exchange of professors by the leading universities was more common in the early days of these institutions than it is even now. Thus the Englishman, John of Halifax, or Holywood, who was known in the middle ages by the Latin form of his name Sacrobosco, studied and probably lectured at Oxford before settling in Paris about 1250. Sacrobosco's "Algorism," while by no means the first European work on the Hindu art of reckoning, was one of the most widely used and

served largely to spread the knowledge of the numerals which we now employ. This "Algorism" was first published at Strassburg in 1488 and at least thirteen other editions followed before fifty years had elapsed. In the first edition it appeared with a computus, the title applied to works on the arithmetic of the church calendar. The Latin version of our rhyme "Thirty days hath September," etc., appears in this "Compotus Manualis" (in verse) and was written by Anianus, a Strassburg astronomer and poet. The name algorism was applied for some five hundred years to the arithmetic which explained the method of reckoning with the Hindu-Arabic numerals. The word is a corruption from the name of Mohammed ben Musa, al- Khowarazmi, whose Arabic work on this subject was translated into Latin in the early twelfth century. Early manuscripts of Sacrobosco's classic are found in the Columbia Library as well as in the Plimpton collection.

Many theologians and churchmen, among the earliest of these may be mentioned the Venerable Bede (c. A.D. 700), and Cassiodorus (c. A.D. 550), amused themselves by writing arithmetics, but this was inevitable in the period when learning was so largely confined to church institutions. Thomas Bradwardin (c. 1290–1349), who was professor of theology at Oxford and later archbishop of Canterbury, wrote extensively on mathematics. His name suffered, as did many others, at the hands of transcribers, being found as Bragwardine, Brandnardinus, Bredwardyn, Bradwardyn, de Bradwardina and de Bredwardina. Another of these professors of theology was Christian Ursinus (also known as Allassiderus, Allassisiderus, Wursteisen or Urstis) who published in 1579 at Basel an arithmetic entitled "Elementa Arithmeticæ."

The surnames, as noted above, were rather shabbily treated from the modern point of view, since the first names were regarded as the important ones. It was common, too, for scholars to Latinize their names, or more rarely to give the Greek equivalent. The reformer Melanchthon, who appears as a writer on the nature and value of mathematics, was baptized Schwarzerd. Schreiber (c. 1525) became as a writer of school texts Grammateus, but was also known as Scriptor. Melanchthon's friend, Camerarius, who was also a classical scholar, was born as Liebhard. Camerarius wrote a commentary on the arithmetic of Nicomachus. Conrad Dasypodius, whose family name was originally Rauchfuss or Hasenfuss, wrote two works which should have been included in this catalogue. Copies of these rare books, both published at Strassburg in 1567–1570 and 1593–1596, respectively, are found in the Astor Library. The older one is entitled "First and Simplest Mathematics," and is partly in Greek and partly in Latin, treating of geometry, logistic (a Greek name for practical arithmetic), astronomy and geography. The writer was professor of mathematics at Strassburg

towards the end of the sixteenth century and he designed the famous clock of the Strassburg cathedral.

The unusually large number of physicians (eleven) appearing in the "Rara Arithmetica" is at first sight rather surprising, until we recollect that the scientific training of the time was largely confined to medicine. Some of these men might be counted among the best mathematicians of their day, notably the Italian Hieronymus Cardan (1501–1576) who attained fame as an algebraist, and the German Johann Widmann (fl. c. 1490), who wrote one of the first arithmetics in the German language. An English goldsmith is the author of a practical arithmetic, of which there were many designed especially for merchants and tradespeople. Jurists and numerous professors of Greek and Hebrew mingle here with priests and bishops and even two cardinals, Petrus de Alliaco and Nicolaus Cusa. The reckoning masters so frequently mentioned as authors remind us that for many years arithmetic had no place in the schools, and that the reckoning masters taught the art of reckoning outside of school hours very much as music and dancing are taught to-day.

Especial interest attaches, of course, to the first arithmetic to appear in print, the anonymous Treviso arithmetic of 1478. While there is no proper title page, the first page begins as follows: "Here commences a practical treatise, very good and very useful for any one who wishes to learn the art of merchants, vulgarly called the art of the abacus." The last page states that it was printed at Treviso (just north of Venice) on the tenth day of December, 1478. There are 124 unnumbered pages, running about 32 lines each. The first page is reproduced in the "Rara Arithmetica" in facsimile, together with three other pages. The author was evidently a teacher in Treviso, as he states that the book is written at the oft-repeated solicitation of his students; the printer's name is also unknown. Peculiarly enough this practical arithmetician applies four different names to the science, two as in the above title and further the art of "*arismetrica*" and *algorism*. This particular copy was in the Pinelli collection, and was acquired in 1790 by a Mr. Wodhull. Later it found its way into the library of Brayton Ives and at the sale of that library became the property of Mr. Plimpton. The work is strictly speaking an "algorism" since that title implied the use of the Hindu-Arabic numerals for practical computation, whereas "arithmetica" designated a theoretical treatise based largely on the work of Nicomachus and Boethius. An "abacus," strictly speaking, would be a work involving the use of some ruled surface or device to separate by columns (or rows) the units, tens, hundreds and thousands, etc., from each other. However these terms were not strictly applied, Leonard of Pisa's extended explanation of the Hindu reckoning appearing under the title "Liber Abbaci" or

"Book of the Abacus," while "Algorithmus Linealis" was applied to numerous works explaining the reckoning on lines which was a slight variation of the abacus idea.

The beautifully printed Calandri arithmetic of 1491, the first in De Morgan's list, differs from its predecessors in having the traditional problems copiously illustrated. The slow-moving snail, who climbs up by day one seventh of a foot and slides back by night one ninth of a foot, is seen here with his head just emerging from the fifty-foot well and looking remarkably active after a climb of 1,575 days. The title page presents Pythagoras as "Pictagoras arithmetice introductor," the wholly erroneous but wide-spread notion being that this philosopher was the originator of the science of numbers.

Of the eight or ten arithmetics (two being parts of compendiums) given by this catalogue as preceding Philippi Calandri's treatise the three following are of general interest. "Prosdocimi de beldamandes algorismi tractatus" (Padua, 1483) contains probably the first reference to a slate; Pietro Borghi, one of these successful text-book writers, wrote the most elaborate of the early books on the subject and more than any other set a standard for the arithmetics of the succeeding century. This text-book for the use of merchants, written in Italian, appeared at Venice in 1484 from the press of Ratdolt. Widman's German text of 1489 employs for the first time the + and — signs, but simply as warehouse symbols of excess or deficiency.

One of the rarest of the catalogued treasures is the "Arithmetica" or "Compendium of the Abacus" (Turin, 1492) of Francesco Pellos (Pellizzati). It appears that this native of Nice came very near to the invention of decimal fractions, writing almost a hundred years before the first complete explanation of the subject in "La Disme" or "The Decimal" by Simon Stevin the Hollander. Pellos actually used a decimal point to indicate division by such numbers as 100, but its full significance did not dawn on him.

The first printed discussion of arithmetic in the English language is a chapter of Caxton's "The Mirrour of the World or Thymage of the same" (London, 1480); the section begins "And after that of Arsmetrike and whereof it proceedeth." An interesting sidelight is thrown on early American history by the announcement of the discovery in Madrid of the first arithmetic printed in the western hemisphere. Extensive printing was done in Mexico in the second half of the sixteenth century, and it was here that Juan Diaz Freyle published in 1556 the Spanish "Compendium . . . with Certain Rules of Arithmetic."

Of necessity many works apparently unrelated to arithmetic are introduced. The fine distinctions between the sciences did not then exist, so that an astronomer, a geometer, a philosopher or a writer on the Church calendar would not hesitate to bring into his subject a dis-

cussion of arithmetic. Finger reckoning and a number game called Rithmomachia are other related subjects which received elaborate treatment. The first modern encyclopedia to appear in print is the "Epitome of all Philosophy" by the Carthusian monk Gregorius Reisch, the publication appearing in Strassburg in 1503. "Pythagoras" and "Boethius" adorn the first page of the part devoted to arithmetic.

It would appear that scientists have, in the course of centuries, grown more modest in their published claims. Borghi's "Noble work of arithmetic treating all those things which are requisite for merchants" sounds like a boast. More seductive are "The Ground of Artes," "The Castle of Knowledge," "The Pathway of Knowledge" and "The Whetstone of Witte," mathematical works by Robert Recorde, the royal physician to Edward VI. and Queen Mary. Recorde was the first to use the present equality sign, stating that no two things can be more equal than two such lines. His were the most influential English mathematical publications of the sixteenth century. Equally enticing as the titles of Recorde was Humphrey Baker's "The Well spring of Sciences, Which teacheth the perfect work and practise of Arithmetick, both in whole Numbers and Fractions" (London, 1562).

The most fitting name with which to terminate a discussion of the printed arithmetics of the sixteenth century is that of Adam Riese. So widely were his books used and so deep the impression which they made that even to-day, nearly four centuries after he wrote, the expression to reckon "nach Adam Riese" is common in Germany. Riese's works quite supplanted the numerous editions of the Rechenbuch by the versatile Jakob Köbel, who was Reichenmeister, printer, engraver, woodcarver, public official, as well as a successful text-book writer. Köbel's "Rechenbuch" of 1514 bears silent but eloquent testimony to the tremendous inertia that must be overcome by any new system that revolutionizes the common processes of thought. Köbel's arithmetic, four hundred years after the Hindu-Arabic numerals had been explained in Europe, is wholly in Roman numerals, even to the fractions. Riese's work made the publication of any other arithmetic in Roman numerals impossible.

Part II. of the "Rara Arithmetica" treats of the rich collection of mathematical manuscripts in the Plimpton library. The oldest of these is a beautifully written Latin Euclid (about A.D. 1260). This manuscript appears to be the copy given by the translator Campanus to Jacques Pantaleon when he was Patriarch of Jerusalem. Campanus was chaplain to Pantaleon both in Jerusalem and later when that churchman became Pope Urban IV.

An arithmetic written about 1339 by Paolo Dagomari, also known as Paul of the Abacus, furnishes the clue to the derivation of our per cent. symbol. The sign is derived from the abbreviation c° for cento

(hundred), and its evolution is traced through later manuscripts. As interesting, but not as conclusive, is an illustration from a fifteenth-century manuscript containing the possible progenitor of the dollar sign.

A beautifully written and illuminated copy of the Boethius arithmetic, written on vellum about 1294, is one of the most valuable pieces; the pigskin binding is of about the same date as the text. Just as valuable, because of the rarity of the material, is the copy of al-Khowarazmi's Algebra, a Latin manuscript of 1456. The title is "Book of Mohammed on Algebra and Almuchabala, or Restoration and Opposition." The word "algebra," like the words alchemy and almanac, is of Arabic origin, having the meaning "to restore." So a surgeon, restorer of broken bones, is called in Don Quixote an "algebrista." The word "almuchabala" contains the idea of balance. Both of these terms were applied to early algebras appearing in Europe.

That no expense has been spared in the preparation of the "Rara Arithmetica" is shown by the 255 photographic reproductions, largely full-page, which constitute one of the most valuable features for bibliophiles and librarians. The tremendous labor involved in searching out twelve hundred printed works, as opposed to De Morgan's one hundred, can be understood only by one who has tried to make a complete bibliography of any subject. The citations and references which have been given are sufficient to indicate the fundamental importance of the "Rara Arithmetica" in the history of the development of arithmetic. The actual additions in the notes, to our present knowledge, are entirely too numerous to mention. They show that the library offers a rich field for research in the history of mathematics. Bibliographically the "Rara Arithmetica" will always be an authority in so far as arithmetical books of the period treated are concerned and Americans may justly be proud that this work, which in the nature of the subject might have been considered more properly the field of a European scholar, has been so ably and finally done by a Columbia professor.

The first of the great collections of mathematical works at all to be compared with Mr. Plimpton's was made by Guillaume Libri, the author of the "History of the Mathematical Sciences in Italy." The first volume of his great work was just off the press at the time of the great fire in Paris in 1835. Libri, who had been at the printer's, took a few copies home under his arm; the rest were destroyed. One of the copies preserved, to which Libri made corrections for the second edition of 1838, is on exhibition in the museum of Teachers College, having been bought in Italy by Professor Smith.

Libri began his mathematical career as a boy prodigy, for at the early age of fifteen he was in correspondence with famous mathematicians, and at the age of twenty he was appointed professor of mathematics in the University of Pisa. Being exiled from Italy for political

reasons when he was twenty-eight years old, he took up his residence in Paris and later became a French citizen. His remarkable ability won him in the brief space of three years the chair of mathematics in the College of France and admission to the Academy of Sciences as successor to the great French geometer, Legendre. His activity extended to the political field as inspector-general of public instructon and later as inspector-general of the libraries of France. Soon difficulties of another nature overtook him, as he was accused of appropriating books and manuscripts from French libraries to his own use, in spite of the fact that he had previously offered his valuable collection as a whole, consisting of some 30,000 books and 2,000 manuscripts to the Royal Library of Paris on the rejected condition that it be kept intact as the Libri Collection. His conviction of the misuse of the national libraries occurred, many say unjustly, in 1805 and he was again an exile, living in England as a fugitive from the law; we will not say justice. His library was sold at auction in England, many of the works finding their way into the hands of Prince Boncompagni and after the dispersal of his library into the Plimpton collection and the private library of David Eugene Smith.

Prince Baldassarre Boncompagni, who gathered together a second famous collection of mathematical books and manuscripts, came naturally by his interest in scientific work, as he belonged to that same princely family as Pope Gregory XIII., who revised the calendar. While eminent as a contributor to mathematical literature, Boncompagni's greater service was as a patron of the science. At his own expense he published the "Bulletin of the Bibliography and History of the Mathematical and Physical Sciences," running through twenty volumes, with many valuable contributions by German, French and Italian scholars to the history of mathematics and astronomy. Even more important were his numerous publications in regard to Leonard of Pisa, who flourished at the beginning of the thirteenth century and to whom was due in a large measure the spread of the Arabic numerals in Italy and Europe. The publications of Boncompagni included two large volumes of the writings of Leonard of Pisa and two Latin versions of the Arabic work of Mohammed ben Musa, al-Khowarazmi, who made the Hindu art of reckoning known to the Arabs in the early ninth century; these Latin versions were made by a Spaniard and an Englishman, both of whom studied at that Moslem center of learning, Toledo, in the early twelfth century. Prince Boncompagni's magnificent collection was offered, on certain mild conditions, to the city of Rome, but was refused. While in printed works of the fifteenth and sixteenth centuries this library was not as complete as is the Plimpton, yet the equal of this collection of old mathematical manuscripts will doubtless never again be held by any private library. The sale at auction of these books took place as recently as 1898.

The small collection of Augustus De Morgan is worthy of note, as it furnished the stimulus for the publication of the first work dealing wholly with the bibliograhy of arithmetic, De Morgan's "Arithmetical Books," published in London in 1847. Of the fifteenth and sixteenth centuries De Morgan described some seventy arithmetics, while the "Rara Arithmetica" describes well over four hundred. A quotation from the prefatory letter by the great English mathematician in which the book is inscribed to the Rev. George Peacock, a writer on the history of arithmetic, is worth giving: "The most worthless book of a bygone day is a record worthy of preservation. Like a telescopic star, its obscurity may render it unavailable for most purposes; but it serves, in hands which know how to use it, to determine the place of more important bodies." De Morgan's felicity of expression in his numerous publications—he was an extensive contributor to encyclopedias—suggests his kinship to the present popular novelist, William Frend De Morgan, his son.

While the "Arithmetical Books" by De Morgan dealt wholly with arithmetical works, many others have treated the bibliography of mathematics. One of the earliest to give fairly extensive bibliographical references to mathematical literature is the "Kitab al-Fihrist," or "Book of Records," an Arabic treatise written in A.D. 987. The mathematical section of this large book was translated into German by H. Suter and appeared in Leipzig in 1892. The author, who went by the melodious name of Abou'l-Faradsch Mohammed ibn Ishak, or more commonly by the name Ibn Abi Ja'kub al-Nadim, included all the writers known to him, of whatever nationality. The Kitab al-Fihrist is of the greatest importance in the history of mathematics, as it is, indeed, in the history of the development of christianity, for the writer describes various early sects of the christians. An appreciably large part of our knowledge of Greek mathematics comes from such Arabic sources, for the Arabs kept the spark of Greek learning alive while Europe was in the darkest of the dark ages.

Our interest, however, is in the bibliographers who treated the early printed works. Gerard Joannis Vossius in 1650 published in Amsterdam his work, "On the Four Arts," which is an unreliable mixture of bibliographical and historical material. Naturally many histories of mathematics treated also the bibliography of the subject. The first German work to attempt a somewhat complete list of early printed books in mathematics was the "Einleitung zur mathematischen Bücherkentnis," which J. E. Scheibel completed in 1769 and of which at least two editions appeared. Other German publications, purely bibliographical, are F. G. A. Murhard's "Literatur der mathematischen Wissenschaften" of 1797 and J. Rogg's "Handbuch der mathematischen Literatur," which catalogued and described books from the invention of

printing up to 1830. The more general treatises on bibliography like those by Graesse and Hain and Copinger also touch this field, although of necessity only incidentally.

Aside from these there have been some purely national works like the "Bibliography of the Lowlands" of the mathematical and physical sciences by Bierens de Haan and the "Biblioteca Mathematica Italiana," by Pietro Riccardi. Professor Smith's "Rara Arithmetica" contains, for the period which it treats, more titles of Italian works than does Riccardi and more German than does Murhard or Rogg. In general, we may say, it is more complete for its specialty than any of the bibliographies hitherto published. The "Rara Arithmetica" may be said to be, with the exception of slight additions, the final bibliography of this field. It may safely be predicted that for centuries to come no other authority will appear to contest its claim to first place.

JOHN DEE AND HIS "FRUITFUL PREFACE"

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IT may be necessary to introduce this "faithful student of the school of verity," for his contribution to human thought was of the kind that is easily absorbed in the sum total of the period, while the man himself remains little known to any but his contemporaries. The writer's introduction to him was through his "fruitful preface" to the first translation of Euclid's "Elements" into English printed in 1570.

That long preface is an interesting document in the development of intellectual freedom as well as in the history of science. It was addressed not so much to learned men as to the author's countrymen at large, though there was an occasional side glance at the university pedants. It expresses ideas strikingly like those for which the name of Francis Bacon stands, though written when Bacon was a boy of nine years. In it the author makes a vigorous appeal to the men of the time to shake themselves free from the commentational habit of the middle ages—to consider that the Greeks and Romans, who were held in such reverence, had not achieved all that was to be achieved. "Master Dee" was fully aware of the state of opinion that must be contended against. He says:

> Well, I am nothing affrayde of the disdayne of some such, as thinke Sciences and Artes to be but Seven. Perhaps those such may, with ignorance and shame enough, come short of them seven also: and yet nevertheless they can not prescribe a certaine number of Artes: and in each certain unpassable boundes, to God, Nature, and man's Industrie. New Artes dayly rise up: and there was no such order taken, that all Artes should in one age, or in one land, or of one man be made knowen to the world.

The immediate and ostensible purpose of the preface was to attract attention to the newly translated "Elements." The author begins:

> Neither do I think it mete for so strange matter (as now is ment to be published) and to so strange an audience, to be bluntly, at first put forth without a peculiar Preface.

In his pride in the achievements of England in the reign of Elizabeth, John Dee was at one with his countrymen, and whether consciously or unconsciously he appealed to men through the motive dominant in that period when he explained at great length how the "wonderful applications of mathematics" might be used for the glorification of the country. At the same time, the author sounds in advance a distinct seventeenth century note in suggesting that the laws governing natural phenomena might be better understood by being treated mathematically, and foreshadows the modern "Præcisions and Approximations-mathematik" when he speaks of "allowing somewhat

to the imperfection of Nature not answerable to the preciseness of demonstration."

The preface is framed for such

who well can, (and also will) use their outward senses to the glory of God, the benefite of their Country, and their own secret contentation, or honest preferment on this earthly Scaffold. To them I will orderly recite, describe and declare a great number of Artes, from our two Mathematicall fountaines, derived into the fields of Nature. Whereby such Sedes, and Rotes, as lye depe hyd in the ground of Nature, are refreshed, quickened, and provoked to grow, shote up, floure, and give frute, infinite, and incredible. . . . At this time I define an Arte to be a Methodicall complete doctrine, having abundancy of sufficient, and peculiar matter to deale with, by the allowance of the Metaphysicall Philosopher: the knowledge whereof, to humaine state is necessarye. And that I account, an Art Mathematicall derivative, which by Mathematicall demonstrative Method, in Numbers, or Magnitudes, ordereth and confirmeth his doctrine, as much and as perfectly, as the matter subject will admit.

It seems certain that John Dee had also a conscious belief in the value to science itself of the application of its principles. He invites his reader to "consider the infinite desire of knowledge, and incredible power of man's Search and Capacitye how, they jointly have waded farder by mixtying of speculation and practise." Compare with this a sentence by Ernst Haeckel written three centuries later:

We must welcome as one of the most fortunate steps in the direction of a solution of the great cosmic problems the fact that of recent years there is a growing tendency to recognize the two paths which alone lead thereto—experience and thought, or speculation to be of equal value, and mutually complementary.[1]

John Dee's long life covers a dramatic period in the history of the development of thought, and as the most widely known English scholar of his generation his education and wanderings are interesting. It was in 1526 that the books were burned in Oxford in the futile attempt to stop the new learning. In the following year John Dee was born of the ancient family of Dees of Radnorshire. His father, Rowland Dee, was by some accounts a vintner in London, by others he is described as gentleman sewer to Henry VIII. Whatever his occupation, he was a friend to the universities, and in 1542 sent his son to St. John's College, Cambridge. Here he remained, first as student, then as foundation fellow, until 1546. When in the same year Trinity College was founded by patent of Henry VIII., Dee was made one of the original fellows and was, as he says, assigned there to be the "under reader of the Greek tongue." At the same time he was occupied with mathematical and astronomical studies and on "going down" gave to Trinity his astronomical instruments.

At that time the men of the universities seemed not to aspire to know more than was to be learned from Plato and Aristotle. That John Dee had a mental appetite beyond the ability of Cambridge to satisfy appears from his account of his wanderings.

[1] "Riddle of the Universe," p. 18.

After I was Batchelor of Arts, I went beyond the seas (Anno 1547—May) to speak and confer with some learned men and chiefly Mathematicians. . . . Anno 1548 I was made Master of Artes. I became a student at Lovain 1548 midsummer, and there I made abode, till the 15th of July 1550. . . . From Lovaine I took my journey towards Paris Anno 1550, . . . where within a few days (at the request of some English Gentlemen, made with me to do somewhat there for the honour of my Country) I did undertake to read freely and publicly Euclid's Elements Geometrical . . . a thing never done publicly in any University of Christendome. My auditory in Rhemes College was so great . . . that the Mathematical Schooles could not hold them; for many were fain, without the schooles at the windows, to be auditors and spectators as they best could help themselves thereto. I did also dictate upon every proposition, besides the first exposition.[2]

John Dee was held in high esteem not only in Paris and Louvain, but at almost all the courts of Europe. He relates (and there is no reason to question the statement) that he might have served five Christian emperors, namely, "Charles V, Ferdinand, Maximilian, this Rudolph and this present Moscovite," but Queen Elizabeth "very graciously" took him into her service. Just what the service was that is referred to here is not evident, but the Queen called upon "Master Dee" for a great variety of services. At one time he instructed her in astrology, using the book which he had written for the Emperor Maximilian. Once he was sent for post-haste to prevent mischief to her majesty's person apprehended from a waxen image of her, found in Lincoln's Inn Fields with a pin stuck in its breast. In 1577 the queen sent for Dee to come to Windsor on account of a comet, and for three days she listened to his discourse and speculations on the subject. Five years earlier there had appeared a brilliant star in "Cassiopeiæ" that caused such consternation among the people that John Dee and Thomas Digges united in an attempt to give an explanation and bring to an end the terror of the people. As a result Dee printed in 1573 his "Parallacticæ commentationis praxeosque nucleum," but not content with that, he printed in the same year a work entitled "de Stella admiranda in Cassiopeiæ asterismo cœlitus demissa ab orbem usque Veneris." Knowing the superstitions of the times, Dee frequently urges the desirability of man's understanding nature. After enumerating various natural phenomena, he asks:

Is it not commodious for man to know the very true cause, and occasion naturall? Yea, rather, is it not greatly against the Souverainty of man's nature, to be so overshot and abused, with thinges (at hand) before his eyes?

In 1580 the queen desired to know her title to countries discovered in different parts of the world and Dee drew up for her two large rolls of description and maps which were approved by the queen and Lord Burleigh. Not only the queen, but explorers, men of affairs and the learned men of Europe sought him out. To him came Sir Humphry Gilbert and John Davis to talk of the Northwest Passage (John Dee

[2] Dee's "Compendious Rehearsal."

himself wrote two works on navigation). The East India Company called upon him to improve the compass. Certain large landholders in England who had mines extending under their boundary lines came to him to settle their controversy. In 1582 Dee was urging the Queen to improve the calendar, and two years later she and her ministers requested him to make the necessary calculations. The Roman Church amended the calendar on the supposition that all that was done at the council of Nice with regard to chronology was correct and proposed the omission of ten days, but Dee's calculations led him to recommend the omission of eleven days. He agreed, however, to compromise for the sake of uniformity, providing the facts should be publicly announced. The plans were approved by the lay members of the committee, Thomas Digges, Henry Savile and Mr. Chambers, but opposed by the archbishop and bishops on the ground chiefly that the project of reforming the calendar emanated from the See of Rome. The reform was thus delayed one hundred and seventy years, but Dee's able treatise was preserved and was made use of when the change actually took place. The original has passed through the hands of many eminent mathematicians, and is now in the Ashmole collection at Oxford.

This treatise on the calendar, the "Fruitful Preface" and the memorial to Queen Mary in regard to a royal library are the most significant of his seventy-nine works, many of which were never printed. In the last-named Dee called the queen's attention to the fact that with the destruction of the cloisters there was no longer any place of safety for manuscripts, and that these were now being destroyed or scattered broadcast. He set forth the loss this would be to history and science, and proposed that a commission should be appointed to establish a royal library—he himself undertaking to procure copies of famous manuscripts at the Vatican. Whether because of his youth or because of the indifference of the Queen, he was not listened to, but in his own library at Mortlake he collected 4,000 books, of which he tells us "700 were ancient manuscripts in Greek, Latin and Hebrew."

John Dee early accepted the Copernican theory and was apparently among the first to understand and give due weight to the writings of Roger Bacon, to whom he refers as a "philosopher of this land native (the floure of whose worthy fame, can never dye nor wither)." It was to him doubtless that Dee owed his high valuation of experiment in science. He begs of his readers to

> Esteeme one Drop of Truth (yea in Natural Philosophie) more worth, than whole Libraries of Opinions undemonstrated or not answering to Nature's Law, and your experience. . . . Words and arguments are no sensible certifying: nor the full and final frute of Sciences practisable.

That many of the opinions held by Dee were not common among even the learned of his countrymen is evident from the manner in which he exhorts them in his writings. He too held out a hand to "divine

Plato," sometimes with an apology, but from his influence Dee had escaped farther than he himself perhaps knew. The amount of space given in the "Fruitful Preface" to the explanation of the uses of mathematics and the record of his varied activities give abundant proof that this scholar believed in making knowledge effective for the benefit of mankind. It is impossible to go through his writings without suspecting that here is one source of Bacon's ideas. John Dee preceded Francis Bacon at Cambridge by thirty years, and were there no positive proof of their acquaintance it would not be probable that a man known all over Europe for his learning and frequently called into service by the Queen and her ministers should remain unknown to a young courtier with the omnivorous intellect of a Francis Bacon. For many years Dee kept an intermittent diary on the margin of his almanac in which is found this note:

Aug. 11—1582. Mr. Bacon and Mr. Phillips of the court called.

Sir Nicholas Bacon was prominent at the court of Queen Elizabeth and his two sons, Anthony and Francis, were court favorites, while yet in their teens. As Sir Nicholas died in 1579 and Anthony Bacon was on the continent in 1582, the "Mr. Bacon of the court" could not well have been other than the young Francis. According to Bacon's own testimony, he wrote his first letter on the "Instauration of Philosophy" about 1583.

Looking at this "faithful student of the school of verity," this "old forworne mathematician," as he styles himself, we see a scholar familiar with the contributions of all men up to his time, a pilgrim to every shrine of knowledge; we see a councillor of kings, an adviser of explorers and men of affairs, a proud patriot, a profound believer in the ability of man to obtain sovereignty over the forces of nature, a courageous man throwing down the gauntlet to authority. But there is a reverse side to the picture. The desire to force the secrets of nature, of which he had a deep presentiment, became a ruling passion. In the midst of a discussion of "Statike (experiment of the Balance)" he breaks off with this prayer:

Oh that men wist what profit, (all manner of ways) by this Arte might grow, to the hable examiner and diligent practiser. Tho only, knowest all things precisely (O God) . . . who hast created all things in Number, Waight, and Measure: and hath wayed the mountains and hils in a Balance: who hast peysed in thy hand both Heaven and Earth, . . . and being farther advertised by thy merciful goodness that, three principall wayes, were, of thee, used in Creation of all thy creatures, namely, Number, Waight and Measure, and for as much as of Number and Measure, the two Artes (ancient, famous, and to humaine uses most necessary) are, all ready, sufficiently known and extant: This third key, we beseche thee (through thy accustomed goodness) that it may come to the nedefull and sufficient knowledge of such thy servants, as in thy workmanship would gladly finde thy true occasions. . . . Amen.

Mervaile nothing at this pang (godly friend, you Gentle and Zealous Student). An other day perchance, you will perceive, what occasion moved me.

Could John Dee have lived another century he might have found in the work of Isaac Newton some answer to his prayer. The very intensity of the longing to understand the mysteries of the universe was in part the cause of the errors into which he fell. His belief in astrology and in the value of the alchemical experiments on which he spent so much of his energy and substance may be accounted an error of the time rather than of the individual, but his long connection with Edward Kelley—charlatan and magician—is not easily reconciled with his intelligence. Kelley, at first an apothecary, became an avowed dealer in magic and seems, for a time, to have made a complete dupe of Dee, who in all good faith admitted him as a valued assistant in his researches and travels. Between the years 1582 and 1589 they were making alchemical experiments, peering into crystals, communing with spirits, etc.—part of the time in England, part of the time on the continent—chiefly at Prague. When in 1590 the real character of his masterful assistant became apparent, Dee experienced the keenest sorrow over misplaced confidence.

But for the time of his wardenship of Manchester College, 1596–1604, he spent the remaining years of his life at Mortlake in poverty and sadness. Queen Elizabeth, in passing to and from Richmond, often stopped to question and console him and sent her own physicians when he was ill. From the records of the time "Master" Dee seems to have made a deep impression on the people round about, both because of his learning and of his handsome presence. Aubrey speaks of him as a great peacemaker among his neighbors, and adds "a mighty good man was he." By some Dee was accounted a conjuror, and so oppressed was he by the charge that he petitioned James I. in 1604 that he might be tried and cleared of the horrible slander. After the king had inquired into the nature of his studies the petition was refused as unnecessary. Up to his death in 1608 Dee retained the profoundest interest in experiments. His magic crystal and cakes are preserved in the British Museum.

Though his actual contribution to science was not great, John Dee belonged to and had an important part in the transition from the commentatorial period of the middle ages to that time of bold originality and vivid reality—the time of Bacon, Kepler, Galileo and of their young contemporary, Descartes. His eyes at least were above the plane on which Francis Bacon stood. Forerunners such as Dee prepared the way for the stupendous achievements of the seventeenth century—that century made notable by the introduction of the most powerful mathematical methods and by the use of these methods to obtain an understanding of the laws that govern the phenomena of nature.

THE MAKING OF THE SCIENTIFIC INVESTIGATOR

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THE question is old but important, how far a man may influence his destiny and career by power of will and by training. Very often it is argued that his future lies entirely with himself, that he is modeling clay in his own hands. From this comes the expression of "the self-made man." Yet "there's a divinity that shapes our ends, rough hew them how we will," a might that the biologist calls inheritance. For by no manner of endeavor can a man make himself a bird or fish, nor can he divorce his mind from his body. An organism may be introduced to new conditions of life, by volition or by circumstance, and though it may change to some extent, it can not become entirely different from what it was at the start and still continue to live. As the twig is bent the tree inclines, that is, bends off from the normal path, but it does not become another kind of tree. The gardener can change the growth of a flower by placing certain solutions in the soil, but he simply adds another substance to it; or the experimenter can prevent a skeleton from developing by withdrawing from the medium certain salts, but he has only subtracted a certain substance. Some qualities may receive an added impulse, others may be retarded, monsters may be engendered, but no man has yet changed one being into a very different one.

Thus there are genetically diverse kinds of beings, and this is as true for men as for the rest of creation. What will be the outcome of any individual is to greatest extent a matter of his inheritance, it is blood that tells. All of us make our advent naked and helpless, all seemingly equally dependent upon the maternal care, all have to learn by experience. Yet no two human infants are alike, except to the inexperienced eyes of an old bachelor, for because they are of different parentage they possess at the beginning different qualities, and it is probable that infants are as unlike as full-grown men and women, though in not the same ways. Indeed, every step in our growth has been conditioned by our ancestry. For the organism is much more than a set of substances and structures, it is a chain of processes linked continuously with the remote past and the outcome depends very largely upon the initial condition. This is the cardinal point that educators have grasped only recently, and about which some of them are still strangely in doubt. A man can not mold himself entirely, nor can his teachers wholly change him, for he is largely fashioned by his inheritance.

But though inheritance handles the reins, the course of life depends

much upon the finding of the right road. Only the *Universalgenie,* if such exist, could arrive at the goal by any of the divergent roads.

The true aim and project of the university seems to me to be, in the first instance, to help the man to find himself, and only in the second instance to educate him. For the reason that this may appear an unusual view it should be explained. Universities arose out of the desire for freedom of thought, out of the wish to break the fetters of formalism. At various times, at Salamanca and Bologna, Strassburg, Paris and Oxford, assembled groups of men who had become dissatisfied with the crystallized curriculum offered by the church schools, who felt the curb on thought. Consequently they segregated, and from their number selected those men as teachers who had new and fertile ideas. Thus within such an assemblage all subjects came gradually to be professed, and each man chose his disciplines according to his inclinations. That is to say, universities in their inception were places for freedom of choice of subject, and this has remained the ideal in at least the more influential continental universities. One expression of it is our elective system, but it is pursued still more broadly in Germany. There the student comes from the fairly rigid curriculum of the Realschule, or the still narrower course of the gymnasium, to the university where he may select just as many courses and just what ones he cares for. The result is a double one: he frequently chooses as few lectures as possible, and then enjoys several Bummeljahre; but drones are no honey getters, and, provided he need a profession, he sooner or later comes to hear lectures on a great variety of subjects until he finds the one that most engrosses his attention, when he devotes himself to that. This system, in the nearly complete freedom of choice it allows, offers the fruits of all sciences, so that by browsing in this diverse orchard the student may find his peculiar taste.

A graduate department is not an Eden simply because all are commanded to eat of the fruit of the tree of knowledge. Men come to it from undergraduate courses where they have followed rather delimited curricula; in it they are free to make choice of the profession of their lives. It is the duty of the graduate school, the university proper as seen in the historical setting, to help each man to find himself, which is but a paraphrase of the Socratic "know thyself."

Students come with different innate propensities; they should choose the fruit that comes nearest their hearts. The decisive step towards success is to choose wisely, which means simply to elect that which attracts most strongly. That is, one should place himself in the soil for which providence or his inheritance meant him, for only by so doing can one develop his capabilities to the full. And if there be one duty set upon us, a duty to our neighbors as well as to ourselves, it is to do that for which we are best fitted, granted only that a man be of sane social judgment.

The occupation of a lifetime is not to be chosen by cold reason, but by the warmth of the heart. When friends go and the purse gets lean, a man may be kept warm by the enthusiasm for his work. When we always recur to our work with delight we make the most of our futures. Much of the success of an investigator lies in his choosing rightly, and the test of one's fitness is the durability of one's zeal.

Many and varied temptations there are to lead one astray from such a choice, the most seductive of which is escape from financial care. All of us can appreciate this, and the more perhaps because the multitude is apt to measure social standing by material wealth. But we will not linger over this time-worn and hoary subject of dispute, beyond noting that such thinkers as Dante and Harvey, who added so marvelously to our understanding of man, were neither rich nor yet in society. What immediately concerns us is that the investigator requires all of his ability to achieve results, and he certainly will have less success if he sacrifice his stronger inclinations for any social or mercenary reason. Let our financial futures take care of themselves, let us guard our talents. There is room at the top; it is only the bottom rungs that seem insecure.

Most men when they have obtained their doctor's degrees feel suddenly helpless, thrown out upon a chilling world. As a result most feel they should secure at once some sort of a remunerative position, and they are apt to think the position better the more it pays. This seems to me to be on the whole a pitiable error, and the reason why is very simple. For if young men have decided upon scientific research they surely will require time for their researches. It is rarely the case that they can occupy any school position and still have opportunity for their own work. Therefore the positions that are best for them are ones that make the least demands upon their time, and most of these are found only in universities. Suppose then a man should be given the choice of an instructorship at $1,500, in a high school or small college in which he would have no time for investigation, and of a graduate fellowship of $500, in which he would have every minute for his work, he should choose the latter no matter what worldly sacrifices he must make. For by this choice he would be gaining time, he would have opportunity to make a name for himself, and if he did not lose heart but remained true to himself he would certainly arrive at the proper kind of a position. If a man become side-tracked into a school teacher's chair, for the poor reason that he gets a living salary quicker, he will never be heard of and never get out of it to realize his ideals. The dollar may seem big, but time is more productive capital than money.

Yet, at the same time, it should be noted that a certain amount of teaching is good for the investigator. For in the first place a body of students enables him to farm out parts of his problem, and by establishing in this way a special school he is able to accomplish much more

than he could single-handed. He can not by himself answer the whole of his problem, but with the help of a corps of students, each prosecuting some particular part, he may be able to; and the students themselves gain by cooperating in such a unified project. For no one man has the ability to follow out all the clues that suggest themselves to his mind. And in the second place, a certain amount of teaching is almost necessary to prevent a man from becoming narrow, and to keep him in active touch with all sides of his subject. It is particularly important for an investigator to teach undergraduate courses, though these are the most difficult to present well, for that keeps him in touch with the broader and more generally comprehensible parts of his work. The occasional meeting with younger and fresher minds is stimulating, and clear presentation of a subject to them often clarifies our own ideas. It is probably on account of their teaching that university men are generally broader than museum curators.

Given then the opportunity to measure the different paths of knowledge, and supposing a man has made his choice congenial and has resolved to stick to it, a great step has been taken. Yet this is, after all, merely the planting of the right seed in the proper ground, much remains before the harvest. To make the simile true we should imagine that the case is one where a man is at once seed, farmer and harvest, limited and constrained by his inherited powers. We have to find our particular effective seed, to set it out with care, and to keep its nurture mainly in our hands.

The subject matter of a science can be taught us, but we have to learn to investigate mainly through our own endeavors. The teacher out of his experience can indicate a problem awaiting solution; he should be able to decide whether it be soluble, but the real work, the research, is with us. One can learn investigation only by investigation, and each man must find his own path through the maze.

Encyclopedic knowledge is often more an impediment than a help to investigation; the two are contradictory. The student may become so charged with scholastic learning that he has no room left for thinking. And as we recall the creative thinkers of the past, we find they were on the whole rather undertrained men, in consequence untired and active in thought, picking up knowledge only when it was needed. For knowledge is not an end but only a tool. Yet there still lingers the idea that during the three or four years the student devotes to his doctorate, he should try to learn the whole of his subject! University teaching, it seems to me, should be called successful only when it helps a man to independent thinking. It is wholesome to recognize our limitations, to realize that we can not carry heavy freight and at the same time make headway. The mind that has to interpret must be fresh and agile, not loaded with the thousand and one opinions of forerunners. Let us avoid burdening our strength with laborious compila-

tion. We sometimes think we are getting wise when we are only getting rusty.

It is this consideration that indicates a man should receive very little help with his doctor's thesis, he should sink or swim without the help of a convenient raft—or professor. For then is the witching time when he is finding out whether he holds the power of research, and he alone can tell whether he has it; he can tell by a certain elation and undefined feeling of strength. The student should be given a soluble problem for his thesis, also certain technical aid, then left rather severely to his own devices. If he succeed he will have proved his ability; if he fail it is still well, for he will be saved from an ill-chosen career. While, on the other hand, the result of aid constantly given is what we may call the "one-thesis man," he who finishes his thesis, to be sure, and gets his degree, but who afterwards, when he is thrown upon himself, proves unable to carry out further investigation. The best test of a leader of a school of investigation is not the number of doctors graduated, but the number who afterwards actively continue to investigate. For their own good students should prosecute their problems so far as possible without extraneous help.

The highest that graduate work can foster is independent thinking, not scholastic learning. A man may be led to knowledge, but he can not be made to think.

There are three particular gifts that the investigator should cherish to his utmost, imagination, judgment and the maintenance of an ideal.

As the insect stretches out his antennæ, feeling and smelling at once, forming thereby an idea of what is ahead of him, so it is that by the help of our imagination we can reach out into the unknown. Blind searching for a clue is not profitable, and it is waste of time to expect some happy fortune to bring an answer to us. Science is not a game of chance. It is necessary to form tentative explanations, and the working hypothesis is the outcome of the imagination much more than of the reason. The reason deals with the known and experienced, it is the imagination that must as a pioneer leap into the unknown. Thus the scientist makes his soundings and feels the depths. He has to forecast various possibilities, and to test these severally. Yet the imagination is only a feeler and not a leg to stand upon. We must bear in mind that hypotheses are but suggestions, invaluable though they be in directing effort, and that the real labor of the scientist is the testing of his hypotheses. The immediate subject matter of all of us, physicist, mathematician, chemist, philologist, whatever our calling may be, is hypothesis, and out of hypotheses we have to reach explanations; an explanation so attained is a theory. We must not confuse hypothesis with theory, nor inflict upon suffering colleagues, much less publish, all our hypotheses. If, as Goethe says, all theory is gray, how colorless must hypothesis be until it has been turned to account.

For these reasons the man of science may be very directly benefited by a study of the great poets, and he will learn thereby how close is the bond between science and art. Yet many still hold the strange idea that the scientist lacks all fancy, as though he could ever explain without the help of it! He who has no gift of imagination has no place in science.

It is by what we call judgment that we measure our hypotheses. This comes in the main from experience, is capable of nurture, and is well characterized as good sense.

In his haste a man may try to run straight through a briar patch, but if he has common sense he will, like the renowned Br'er Rabbit, hunt out some trail; so he will reach the clearing quicker though he can not show so many honorable scars. Herein lies the main value of studying the lives of the masters of thought. Of each man who has markedly advanced knowledge we should make a hero, and humbly try to follow his footsteps by analyzing his methods of work. Indeed, this study of personalities should not be limited to the great, for from every man that we meet we may learn something to help our own working method; that is, we may learn if we try to. Each of us realizes that we can not give a correct estimate of a man's work unless we know his personality, Shakspere always excepted. Therefore to judge of scientific data we can be greatly aided by measuring personalities. It is then suggested, to help us to a sound judgment, to analyze the individualities of others, to see how they came by their results. This is the chief value of all collegial intercourse in seminar and society meetings. A fellow student is often the best of all teachers. And for the same reason it is well worth the time both to study the history of one's subject, that is, the methods and especially motives of its founders, and to read reverently and lovingly classical monographs whether they be now fashinable or not. How many of us do actually read Aristotle, Newton and Helmholtz? It is such study that enables us to see modern discoveries in their proper perspective, and restrains us from fancying each mole hill to be a mountain.

Breadth of judgment may be helped by catholicity of interest. Some men seem to do their best by devoting every energy to one problem, seeing nothing outside of it. Their mind is a short-focus lens with consequent penetration, but it can not see the garden for the weeds. It is perhaps more wholesome, however, and it certainly leads to a nicer mental balance, to respect all good endeavor and to try to understand at least the fundamentals of our sister subjects. This indicates the choice of a problem that is not circumscribed, but that leads into an ever-widening field. It further indicates that we should breed acquaintance with subjects quite apart from our own, to see the relations of our work to that of others. Expression of contempt for any

source of knowledge is an acknowledgment of ignorance, and meagerness of ability is to be measured by narrowness. That investigator with a foreshortened horizon will find everything small.

We hear it said that in science all facts have an equal value, just as all links in a chain have equal importance. If this were so, then all problems of science should have an equal significance and it would make no difference what choice of problems were made. But the premise is wrong, because we generally recognize that some phenomena have very wide bearings while others do not, or at least do not in our present understanding of them. Thus the phenomenon of the size of an animal has not nearly so much significance as the phenomena of its rate of growth or alternation of generations. We measure the value of a phenomenon by the number of ideas we associate with it, that is, its relative degree of complexity. As in art a painting of a basket of fruit, no matter how excellent the technique, can not be compared in value with a study of a human face, so in science the discovery and description of a new muscle, no matter how accurately made, can not be paralleled with an investigation of the process of formation of that muscle. The human face and the process of differentiation call up ever-widening associations, while the basket of fruit and the muscle suggest a meal. To be sure, a master artist might make the basket of fruit appear celestial, and a great anatomist make the muscle seem extraordinary, but they would still suggest a meal, even though a meal for angels or heroes. Men will differ as to the relative importance of any thing, and we have no right to prefer our estimates to others. But it is generally acknowledged in science that the investigation of a process is of a higher order than the contemplation of one particular step, the number of comparisons possible being the criterion of value. Thus it is certain that all problems are not of equal value, because they have very different bearings. All need solution, they are of sufficient diversity to appeal to all types of mind, but a man should assure himself that his problem has really broad significance. And when the layman approaches us on the manner of our work we should not tell him, as is often done, that he can not understand it because he is not a scientist; for if we can not make it intelligent to him it is clear we have no good comprehension of its bearings, and the fault is with us and not with him. Every scientific research has some connection with human interests we should understand what the connection is; if we do not understand this we are to blame for any lack of sympathy. It is a duty of the investigator towards his subject to make it comprehensible to the layman, and when he does so his merits will be acknowledged, but not before.

Like every other process, so thought needs time, and by reflection is meant thought pursued at leisure. When a certain result has been

won in our researches, and its bearings seem misty and uncertain, we gain nothing by filling the ink pot and knotting a cold towel around our heads in full determination to settle matters. Dogged does not always do it. Put the idea away in some corner of the mind to give it time to germinate, then bring it out at intervals for consideration. This mental chewing of the cud is wholesome because natural. When the way seems darkest and most beset with stumbling blocks we may be nearest the door, and it is best to go slowly in the dark. We attain our conclusions at unexpected moments and have generally to wait until they appear subconsciously, the time varying with the individual mind.

It is often an aid to reflection to drop for a while the subject that has begun to worry us, to take up a different and fresh problem. This alternation of subject is a necessary mental recreation and frequently accomplishes more than long hammering. For any change of thought is stimulating.

Yet the investigator need not be like Heine's "gray friend between two bundles of hay," slowly starving to death because he can not decide; it is better that he choose unwisely than not choose at all, else he can not maintain himself in the arena of thought. After all, if he eats one of the bales of hay and learns later that the other was larger and sweeter, he has not gone hungry.

It would seem to be on the average best for the general man to take rather a middle stand in his judgments, which means to see the good in both sides of any question. One should be neither too critical nor too tolerant. New ideas are constantly emerging, many of them contradictory to our own, and we have to cultivate a mode of meeting them, not to be bristling like the fretful porcupine, nor yet to embrace them eagerly because they are new. Also it is not safe to say an idea is wrong because it is new. We should react towards views as towards our fellow men, hunt for the best in them. Nothing is easier than to criticize, nothing less constructive. Life is too short for full achievement, unless Metchnikoff's prophecies may come true, and "Like as the waves move on the pebbling beach, so do our minutes hasten to their end." Then why misuse the moments in picking flaws? In the orchard before us we may readily find the insect-bitten fruit if we look for it, but what pays is to gather the good. Whether it be right or wrong from the philosophical aspect, the optimistic standpoint is the most wholesome, and that man is happy who sees only the good in others—in their personalities as well as in their opinions. We all shun him who has the squinting mind of noting only mistakes. Let us be fair to other men even though we can not be impartial, if only for the reason that it is the best policy, as Franklin would have said. For if we are not so, the retort courteous will be harder than the blow we struck, and then will be our time to wince.

We are least objective about ourselves and that is why we can never decide what is our own merit and achievement. For while the ambition to excel is both justifiable and desirable, the true mirror of success must be the eyes of others. Geniuses are really exceeding rare, yet every man is inclined at some period or other of his existence to think himself one, and a fool continues to think so. On the whole, we do not deserve more praise than we get, the world's estimate being reasonably fair; and in fact it is incorrect to talk of deserts since each man carves for himself his slice out of the cake of his own baking. Perhaps the happiest stand we can take is to lose consciousness of self, to think of results but not of our part in them, to come to comprehend that our subject and the sunlit world outside of us is much more engrossing than ourselves. From the philosophical side this attitude may be incorrect. But a new philosophy is gradually forging ahead, that men do not contain the whole universe in their minds, that phenomena are not wholly subjective, but that nature is one great unit of which we are only inconspicuous morsels. This is certainly the philosophy of biology. It places us in a truer perspective, and aids us to be more objective and therefore happier. Fortune is a fickle goddess who keeps beyond those who seek her, to touch those who made their work their grail. Thus what we accomplish, and how we have done it, is a matter to be decided by other men and usually by other men of a later generation. When we try to boost our own reputations they will surely receive a great fall. Therefore let us try to forget ourselves and not be troubled about our scientific levels. This will also save that waste of time and good paper given to polemics. When some one overlooks our writings or misrepresents them, we are apt to feel we should go him one better, which may force us into such extremes that we think we can not in honor back out. A published polemic is noisome, an airing of one's dirty linen, and springs from a condition of megalocephaly. Our work is with us, our repute with others. By being true to our work we may attain a dignity never to be reached by self pushing. Science is not a business market.

In any scientific inquiry he rightly receives the most credit who presents a definite and positive solution. Such was the case with Pasteur, in many ways the master mind of the nineteenth century; what he undertook he definitely settled. Most men attain to only conjectures, but we should seek indisputable decisions. And a good method is that of Darwin, to formulate a working hypothesis and then try honestly to disprove it. Darwin gave as full and fair hearing to the objections made against the theory of natural selection as to the evidence for it. We may approximate this by using every check and control. For we do not want the elusive possible or probable, rather the decisive actual.

But what especially lends dignity and strength is the maintenance of an ideal. German students in their expansive intimacies discuss their ideals quite openly, their "Lebensphilosophien" as they term them. We Anglo-Saxons are not inclined to talk of such matters. But a man should keep a noble aim in sight and never let it be hidden by the clouds of circumstance. That ideal must be something much grander than any detail we have immediately in hand, our several efforts only approximations towards it. We are, it seems to me, to consider the investigations of science as all directed to one end, though no man will see its consummation, the interpretation of that great melody, the universe. Here is a subject without end, all human knowledge may be employed in its elaboration. Men of the world do not understand why we are busying ourselves with fixing the exact date of the first rendering of a play, the number of times that a certain prefix occurs in the writings of Pindar, the exact length of a heat wave, or the behavior of a particular microscopic particle of one kind of organic cell. And in themselves these are not great things; an average man with patience and training might deal with them. They are on the whole so generally uninteresting that each has the world over only a small group of devotees. But when they are seen as steps in a synthesis of explanations their value is at once apparent. Our business is to weld all these separated bits of knowledge together, to make of them a great sustaining wall. And when the utilitarian inquires what will be gained by this giant effort, be ready with the prompt reply: on this knowledge depends our control of ourselves and of nature. Scientific inquiries are not to be pursued wholly academically, as games to amuse. They are attempts to explain the processes of nature, in order that we may use this knowledge for the advancement of our kind. And it is as true as the night follows the day, that explanation must precede application and consequently human progress.

This is the apology for the investigator. He has to do neither with the cataloguing and rearranging of facts, nor with their transmission, but with the enlargement of knowledge by discovery and intrepretation. Both stand for the development of character, but while the undergraduate work is for the transmission of knowledge, the graduate department is for a higher aim, its increase. If it is difficult to garner and hand over knowledge, it is still harder to add to it, and no faint heart need try to be an investigator.

Our project is to try to decipher the nature of man and of the universe, and for this there is full need of every iota of strength and determination and talent there may be in us.

THE CAUSE OF SOCIAL PROGRESS AND OF THE RATE OF INTEREST

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IT has been generally considered by the scholars of the social sciences that there is no fundamental cause in human societies for social progress. Indeed, the whole Malthusian theory is to the effect that the overwhelming rate of increase possible in human societies tends to keep a considerable percentage of the members of a society on the threshold of continuous poverty. A moral hopelessness characterizes the books of a great many economists, when they touch upon the subject of population. By reason of these gloomy chapters, political economy has been termed the dismal science.

How many established doctrines of good writers have been swept away by the light of subsequent discoveries and later reasoning! Were it not for the high improbability of any one scientific doctrine long standing without modification, I should hesitate seriously before advancing these notes on the views held by me and which are so completely at variance with the long-established and present theories of the science of political economy with respect to population and interest. Yet, because these views have greatly brightened my interest in all subjects of human history, I am interested in subjecting them to early criticism.

There seems to exist in the tendency of populations to increase in numbers the cause of progress, which, if unimpeded by certain destructive agencies, which I have termed to assist me in my thinking the "wastes of nations," would carry along on the waves of comfort and prosperity an ever-increasing population up to an unassignable limit, so great is the possibility at which a stationary state could be maintained. These destructive agencies are not a product of the increase in numbers, but they constitute the elements of the hostile environment against which progress has been continually made since the earliest historic times.

Now a social group on any habitat at a given time exists through the application of a series of arts which are possessed by the society and are exercised over the environment. The arts existing at any time may be inventoried and logically classified. The arts are productive and are ways of doing things which bring a return. There are the arts of the food supply, such as hunting, fishing, agriculture, food preser-

vation and eventually food production by synthetic chemistry in the broader classifications, of house building, of useful clothing, of hygiene, etc. These arts are known in varying degrees of detail to some members of the society.

There may be two specific arts known at a given time useful for the accomplishing of the same result. We are apt to find that art in current exercise which accomplishes the result with the smaller cost of production. It is wonderful to contemplate how very closely cost of production has been studied at all times. In the same classifications, one art successively displaces another on the basis of reduction of cost of production or saving of human effort.

But the art is very different from a material thing. The art is immaterial and useful. Wealth is commonly defined as material and useful. The art as well as the object of wealth may be possessed. The value of wealth, of the material things which are useful, is the shadow of the force of the arts, the immaterial things which create value. We must distinguish sharply some of the characteristics of the arts. Napoleon once said: "But you can not outnumber the one brain."

In a great problem, a thousand ordinary brains put to work on the same problem can not be added together. The results of all this mediocre thinking will not surpass the products of the brain of a Newton, a La Place, or a Napoleon. There is a degree or quality which can not be gained at random by addition. In the mental tug-of-war, it is true that we can not outnumber the one brain. The art is the product of the "one brain," *i. e.*, of the brain of a quality or degree slightly superior to the brains around it. We, therefore, note that a superior brain is a treasure for the community, provided the brain is put to work to solve the problems of the present life.

Now, Professor Karl Pearson and Sir Francis Galton are wont to define the exceptional man as one in a certain proportion of the population. It is assumed that in a strain of the population, there is the "one brain" in a hundred, in a thousand, in a million and in a hundred million of persons, of increasing quality for each classification. Around the lives of the "one brains" are gathered the essential narrative of the history of their times.

But, our first theorem is that the value of an art or of an invention, measured in a saving or a lessening of the previous cost of production, is theoretically commensurable, and that this value for the same new art varies with the population. In other words, the greater the population at a given time, when a new art is discovered, the greater will be the value of the art. If an art, say the invention of the sewing machine in the clothing trade, is equal to saving two dollars per capita per annum net over previous outlay, after making due allowance for new capital invested in the machine, etc., the value of the new art is plainly the

savings per capita multiplied by the population and capitalized at the proper rate of interest for new industries. If the population is one hundred thousand and ten per cent. of a fair rate for capitalization, the above example would produce $2,000,000 as the value of the invention. If the population had happened to be one million, the value of the invention would have been $20,000,000. Consequently, we note that the greater the population the greater will be the value of a new art.

The second theorem is, that the capitalized value of the old arts in current exercise steadily increases with increasing population, since the savings are effected for more people.

As a third theorem, we may assume that the new arts during any period are the products of the inventive or exceptional minds, and that the greater the population, the greater will be the number of exceptional minds of each degree for the various classifications, so that the value of the new arts during a year is the product of the exceptional minds and the average inventive productivity for each degree.

Suppose that in a population of one million, we may expect that the "one brain" in the million will produce an invention capable of saving one dollar per capita per annum over existing arts. Capitalized at ten per cent. the value of one year's product of this mind is ten million of dollars. Now, let us assume that in two million of people, we shall find two such men. The capitalized value of two such inventions as above will be not twenty millions, but forty millions of dollars. In other words, the capitalized value of new inventions for a given time tends to vary at least as the square of the population, and, if we may imagine that the "one brain" in two millions is of higher degree than in the one million of population, the value of inventions will be at a greater rate than the square of the population.

We, therefore, arrive at the conclusion that the comfort and the prosperity of a population tends to increase more rapidly than the population on which it depends; that society tends to progress under the law of increasing returns. It is also interesting to note that through the workings of our law of social progress, the per capita increment of value for arts varies with the population. In our illustrations above the savings for each person in a one million population would be one half that in a two-million population. We find in the above law an explanation of the rise in wages, inasmuch as exceptional men in all degrees tend to receive as wages or remuneration for services of the same per-capita saving a sum proportional to the total population.

All this reasoning is theoretical. The same is true of the writings regarding the Malthusian theory. But it would appear that the steady progress made in average comfort by all nations of the world since the remotest antiquity would favor the former rather than the latter reasoning. It would appear that there can be no more favoring circumstance

than a steadily increasing population, provided the quality and frequency of exceptionality are not diminishing through an untoward reproductive selection.

How carefully should statesmen strive to prevent all hindrances to the successful operation of this fundamental law of social progress which is imbedded in the very nature of knowledge. With what forethought should we strive to prevent the wastes of nations. To the wastes of nations such as disease, ignorance, vice, crime, injustice, bad government, lack of opportunity for the exceptional and war, must we ascribe the hideous catastrophes which have wrecked successively one nation after another.

On account of the above law that there tends to be an annual increase in capital value of the new arts, and varying with the square of the population, we are led to the conclusion that herein lies the cause of interest. In those fields where inventions are being made most rapidly at any time, capital is needed. The savings in part effected by the new arts are paid over for the use of the capital. The existence of an interest rate which, eliminating the element of risk, probably varies between two per cent. and eight per cent. is the shadow of this law of progress which says in substance that the product of the annual work of the exceptional men tends to vary as the square of the population, and it follows that as population slowly increases, this surplus fund comes into existence out of which interest is paid. The above, then, seems to be the major cause of interest, and many known facts are in harmony with this theory. Interest has increased historically in times of rapid invention. It rules highest in industries where new inventions are taking place most rapidly. Interest is higher in new countries where population is rapidly increasing. Further, in the case of nations retrograding through disease, vice, bad government and decreasing population, commercial interest sinks to a very low figure. The elaborate agio theories of interest seem to me to throw no light on the cause of interest. A geometrical increase of wealth, which is so universal, must have an adequate cause. I am aware that there are very many important considerations not touched upon in the foregoing, but in a series of notes, this must of necessity be so.

PARASITIC CULTURE

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IT is a fact well recognized in biology that a functionless organ is not tolerated by nature. In the evolution of life, whenever any organic structure has fallen into disuse, it has forthwith come under the law of atrophy and elimination. Until this law of atrophy and elimination is satisfied, the useless organ is a drain upon the vitality of the organism as a whole. It gives no equivalent for the support it derives from the life of which it is a part. In other words, it is parasitic. As a parasitic organ, moreover, it not only uses up energy that should go to the other organs that have a vital function to perform, but it also tends to become diseased and thus to impair the health of the entire organism.

There are numerous illustrations in the human body of the disuse and atrophy of organs, as well as of the incomplete elimination and disease of such organs. Thus there are many muscular structures, such as those of the pinna, epicranius and the platysma myoides, that are at present functionless and far on the way to complete atrophy. These useless organs are comparatively harmless, though, in strict truth, they must be nourished at the expense of the rest of the organic life. There are other functionless organs, however, that are not so harmless. Such is the vermiform appendix, in man a useless and retrogressive structure, which is apt to become the seat of serious disease. Such also are various functionless ducts, as, for example, the parovarium, which frequently become the seats of tumors, more or less malignant and destructive of life.

All these useless and, in a sense, parasitic organs of the human body, which modern research in the fields of physical anthropology, anatomy and embryology has brought to light and explained, point to laws of development that have a profound significance for every department of effort in which the control and improvement of man's life is an object. These laws are already beginning to be recognized by scientific educators. It is seen that the education of the mind and of the body consists essentially in doing what nature has been doing throughout the biological ages—that is to say, producing favorable variations through adjusting individuals to a progressive environment, perpetuating and perfecting these variations as more efficient organs of life, and getting rid of outgrown and useless organs so that no energy may be diverted

from the channels of vital usefulness. Nature is sternly and rigidly utilitarian, and yet she is splendidly idealistic. Her aim is always an enlarged, and ever enlarging, life, and to this end she can tolerate nothing in her economies that is functionless and therefore an obstacle to progress.

Here, then, is the clue that modern education is beginning to accept for its guidance. As a result, the ideal of general culture in education is being subjected to standards of criticism that are as new as is our better understanding of the nature of life. Men have believed for centuries that certain studies, or forms of discipline, have the peculiar virtue of generating in the mind, or the body, a power, or wealth of resources, that may subsequently be available for any purpose to which mental or physical energy is applied. From the days of the renaissance to the present time, universities and colleges have contended for this ideal of general culture. Mathematics and the classical languages have been regarded as, in a special sense, indispensable to such culture. In the organization of secondary schools, these institutions have been subordinated to university and college entrance requirements. And so throughout our educational system, above the elementary schools, and frequently in the elementary schools themselves, the culture ideal has largely determined the subject-matter and methods of instruction. Thus it is that in our very midst, every boy and girl who looks towards higher education in our standard institutions of learning is compelled to have certain courses in mathematics and the classical languages. Greek has at last been made an optional entrance requirement, but Latin and mathematics still hold their distinctive places. No difference what the ulterior life-purpose of the adolescent boy or girl may be, no difference what their tastes or aptitudes may be, Latin and mathematics they must have; and Latin and mathematics they must look forward to pursuing even after they enter college. All for the sake of the general culture these subjects are supposed to give!

In the light of the biological law of wasted energy and disease, in connection with organs that are parasitic on the life, we are now prepared to estimate this ideal of general culture from a new point of view. And first of all, as being more obviously amenable to this biological law, let us consider the ideal of physical culture. Now it has been contended for generations, in accordance with the general culture ideal, that certain courses of discipline will give a fund of physical energy that may be available for all the demands of subsequent life. Thus physical culture has been separated from the natural, every-day functions of life, and made a matter of general courses of training in the gymnasium. Even since the play-idea of physical culture has come to the front, and the gymnasium has had to share its prerogatives with the athletic field, much of the justification of the undue absorption of

large classes of students in football, baseball and the like, and of the over-strenuous combats waged among them, has been found in the supposed advantage of athletics in storing up a fund of physical energy for subsequent use. The line of reasoning has been the same as in connection with all phases of general culture; namely, that the discipline given, the power acquired, may be applied to all possible physical functions. In academic circles, this view of athletics, whether in the gymnasium or on the athletic field, has not even yet been very generally questioned. While the popular mind, as reflected in the newspapers, universally consoles itself for the bruises and broken bones of the strenuous athletes, with the thought that there is fine discipline in all this, and that the results in subsequent life will amply compensate for present injuries.

But here the accumulated observations and inductions of science have begun to suggest troublesome questions about this more or less artificial muscular development of boys and men. It has been observed by physicians that very frequently athletic types of manhood have weak hearts, weak lungs and weak vital organs generally. Often their health and efficiency in later life are poor; and, in not a few cases, they break down prematurely. These observations have set both medical men and teachers of physical culture to thinking, and we are now being told that there is danger of over-developing the muscular system; that over-developed muscles impose a severe drain upon the rest of the organism; and that all muscular development, unless it is utilized, becomes a tax upon bodily energy, and may give rise to disease. Only very recently a naval officer, who was an athlete while in the naval academy, is reported as having failed to meet the required tests of physical efficiency; and his physician ascribes his failure to his earlier muscular development in excess of the needs of his later life. That is to say, his vitality was reduced through parasitic muscular culture.

All this suggests that we can not store up a fund of physical energy through specially devised forms of physical training. Indeed, the term "general culture" as applied to the organic life is probably a misnomer. The culture we get from gymnastic training and from the athletic field is really special in character, and is applicable mainly, or solely, to the types of physical activity that constitute the training. Hence the energy derived from such culture does not become available for the organism as a whole, but is limited to the special organs that have been trained; and unless these organs continue to perform the functions for which they were trained, they become useless and a detriment to the life. Functionless physical structures derived through the artificial exercises of any form of physical culture thus fall under the general biological law of atrophy, with all its attendant consequences of waste and disease. The only really economical form of physical culture,

biologically speaking, is the culture derived through performing activities associated with the natural, that is to say, fundamental and long-established, functions of life. These are, in general, the spontaneous play-activities of childhood, and the productive work-activities of manhood and womanhood, each performed under normal conditions of stimulus and environment. Neither artificial gymnastics nor the feats of strength and skill performed under the stimulus of the prize-ring or athletic field come under these heads.

How such considerations have begun to affect the thought of critical students of physical culture may be illustrated by the conclusions of Dr. Jules Payot, set forth in his book on "The Education of the Will":

> The qualities of vital resistance are in no way dependent upon muscular strength. A man may be an athlete in a circus, or able to do the heaviest porter work, and yet have very poor health, while another man who lives in his study may have an iron constitution with mediocre muscular power. Not only have we no reason to aspire to athletic strength, but rather we ought to avoid it; because it can only be developed by violent exercise, and such exercises not only interfere with the regularity of the respiration, and cause very distinct congestion in the veins of the neck and brow, but they are undoubtedly weakening and exhausting. . . . We have come to the conclusion, therefore, that it is not England with her violent system of exercise which we ought to imitate in this connection, but rather Sweden who has completely given up such ruinous physical efforts for young people in her schools. There the object is to make young people strong and healthy, and they have perceived, that excessive physical exercises are more sure to lead to a breakdown than excessive study.

Turning now to intellectual culture, we have to consider whether the law of waste and disease, operative throughout the biological world, applies to the unused organs of the mind that have been developed through stunts in mathematics and the classical languages, as there is accumulating evidence for believing it does to physical organs trained in the gymnasium and on the athletic field. Here, it must be acknowledged, our evidence may seem less tangible and conclusive. It is harder, even for minds familiar with the facts of neurology and psychology, to image the special processes of nervous stimuli, the building up of cortical neurones, and the establishing of association-centers involved in mathematical and linguistic study, than it is to image the enlarged biceps of the disciple of punching-bag or gridiron education. For minds unfamiliar with such facts, it is absolutely impossible. Hence the whole process of intellectual culture, both to the average student and to the average onlooker, be he teacher or parent, has no concreteness whatever. It is a mere matter of subjective impression and *a priori* opinion. But the difficulty of our problem need not deter us. Our evidence, however intangible and remote from average experience, is sure to become clearer the longer it is considered in the light of the general scientific facts of life that are gradually becoming so extensively popularized.

To present our problem definitely at the outset, I submit the following proposition: The intellectual culture derived through standardized branches of education, as mathematics and Latin, for example, instead of having a general mental economy for the innumerable young men and women who study them, in reality becomes parasitic in the nervous and mental life, and thus is a cause of wasted energy and, possibly, of disease. This proposition has its proper qualification, of course, in all cases where such intellectual culture is so related to the functions of life that it can be utilized. There are two questions that confront us in such a proposition: (1) Is culture, unused for the specific function that called it into being, of no economy in performing other functions? And (2) is such culture, therefore, parasitic and wasteful of human energy? As has already been pointed out in connection with physical culture, it has long been assumed, and is still generally assumed, that culture acquired through any given discipline becomes a general fund of energy or skill, transferable to other organs and functions. And yet there has never been any really critical evidence in support of such an assumption. The belief in a hierarchy of culture-values, which has standardized the various branches of our academic curricula, like many other beliefs relating to the world of mind and the world of matter, belongs to the category of the naïve, the uncritical and the prejudiced. In most of the learned decisions upon the constitution of this hierarchy, the judge, the advocates, and the jury have merely reflected the nature of their own training, and more especially the interests of their own calling. But we are now in a position to submit this question to the test of exact experiments. This has been done repeatedly within the last few years by experimental psychologists. Among such psychologists may be mentioned James, Gilbert, Fracker, Thorndike, Woodworth, Judd, Bair, Volkmann and Scripture. The net result of these men's studies may be stated in the words of Professor Thorndike, of Columbia University:

> A change in one function alters any other only in so far as the two functions have as factors identical elements. The change in the second function is in amount that due to the change in the elements common to it and the first. . . . Improvement in any single mental function need not improve the ability in functions commonly called by the same name. It may injure it. Improvement in any single mental function rarely brings about equal improvement in any other function, no matter how similar, for the working of every mental function-group is conditioned by the nature of the data in each particular case.[1]

This is direct experimental evidence, and it is fairly conclusive against at least much of the indiscriminate championship of the general culture values of special subjects, like mathematics and the classical languages. Neurology, moreover, supplies additional indirect evidence no less conclusive to those familiar with the histology of the brain.

[1] "Educational Psychology," Chapter VIII.

The study of the development of cortical neurones and association fibers makes it probable that every mental process modifies these nervous elements; so that education, whatever else it may be, is a matter of developing specific nervous organs through which the mind may work. Thus the study of mathematics means, on the neurological side, the building up of cortical neurones, with their association fibers, which shall constitute a mathematical nervous mechanism. So, likewise, the study of Latin or Greek means the building up of nervous structures specifically adapted for those languages. The clinics of nervous and mental pathology tend to show that this probable process of specialization of brain-structures, parallel with special mental activities, actually takes place. Thus when the centers of the brain having to do with mathematical relations are diseased, the subject may lose the power of perceiving mathematical symbols, or of thinking in them. So, too, when the centers of the brain having to do with language relations are diseased, the subject may lose the power of perceiving words, or of thinking in them. That is to say, the elements of mathematical and linguistic experience and culture may be lost, and meanwhile the other elements of experience and culture remain unimpaired. This would seem to prove that human experience is mediated by specialized nervous organs, and that the culture derived therefrom is special, and not general, in character. In fact, it but confirms the conclusions that all scientific students of nervous organs and of mind must reach, in any comprehensive interpretation of the facts.

Here then, is a body of facts and inferences supplied by experimental psychology, the histology of the brain, and nervous and mental pathology, which point to the conclusion that so-called "general culture" is not general but specific, that it affects organs and functions appropriate to the particular study pursued, and that to be of any adequate advantage to the life such organs and functions must continue the activity through which they were developed. There is here, evidently, a vast territory of unknown and debatable ground, but the headlands and mountain peaks stand out more and more clearly for the explorer who approaches the problems of education and life in a scientific spirit and with adequate command of scientific facts. It is clear, for example, that those educators who will subject an adolescent girl to five or six years of severe training in higher mathematics, should be peremptorily challenged as to why they do it. They should be asked to show, in terms more specific and modern than most of the vague opinions one commonly hears about "culture," just how the fund of power that is supposed to be generated by mathematical study, is, in fact, generated; and how it becomes available throughout the girl's subsequent life. So, too, these same educators should be asked to give reason why they compel an adolescent boy to spend five or more years upon the study of Latin before they will accredit him as being educated.

What is there in this comparatively immense expenditure of time and energy upon Latin that will develop organs and functions continuously available for the boy's mental efficiency and usefulness in the world? How does a nervous mechanism, with its infinitely complex system of neurones and connecting fibers, fashioned through and for the study of the Latin language, become adapted for all other mental processes? In short, it is time to read a new and compelling significance into the old query of instinctive common sense as to what is the value of the so-called culture that is doled out to our children in the secondary schools and colleges.

Having thus answered the first question involved in our proposition, it remains to consider the further question of what becomes of useless organs of culture. What is the effect upon the girl's life of having to support an elaborate nervous mechanism for dealing with mathematical symbols and concepts which she never has occasion to use? What is the effect upon the boy's life of having to support a nervous mechanism for declining Latin nouns and adjectives, conjugating Latin verbs, and construing Latin sentences, which he never has occasion to use? May not these unused nervous organs become parasitic upon the nervous vitality, just as the unused muscles of the athlete become parasitic upon the general organic vitality? It may seem to some little less than fantastic to suggest such a result. And yet, if we believe that life is a biological unit, and that the laws controlling it are identical in nature and operation, there is no escaping this conclusion. Moreover, there are many peculiarities in the nervous and psychic constitutions of a considerable number of educated men and women that await a plausible theory to account for them. The suspicion is harbored in many minds that academic communities are apt to become over-cultured. They are apt to lose that balance between perceptual and conceptual experience which is the supreme test of healthy-mindedness. At the very best, they suffer from an hypertrophy of the critical faculties, which reveals itself in philosophical and linguistic hair-splitting. At the worst, it may amount to a nervous tension and general intellectual straining after precision in scholarship and propriety in conduct that creates an atmosphere blighting to spontaneity of work and life in the students. This is frequently illustrated in schools and colleges for girls, where an excess of women teachers, with hypertrophied intellects and atrophied human interests, make education a process of mental arrest and disease instead of growth.

Outside of academic communities, there are to be found everywhere a cultured flotsam and jetsam. Europe has long had its proletariat of culture, and America is rapidly developing one. In the more intense nervous life of America, moreover, there are appearing numerous types of nervous instability among educated men and women. This is illustrated not only in the frequent neurasthenia of the cultured classes. It

is also, and, perhaps, more characteristically, shown in the religious, social and other vagaries that often bring to light strange perversions of human energy. The movement towards the emancipation of women during the past few decades, with all its numerous and positive merits, abounds, nevertheless, with examples of mental and emotional distempers that find their psychological explanation in the strangulated intellectual energies of its votaries. Much of the current unrest among intellectual women is probably due to specially cultivated mental organs that find no adequate function to perform. All these forms of neuropsychical strain and instability are, I submit, at least partially explicable in terms of the useless and parasitic culture, which has become more dangerous to modern society in proportion as it has been extended to the masses of men and women. In earlier generations, when fewer men and women were subjected to the artificial culture of the schools, the general detriment to society was not so obvious. But now that thousands and tens of thousands of boys and girls, and young men and young women, are having their nervous and mental lives fashioned for activities they never have a chance to perform, it may happen that higher education, instead of being a means of racial advancement, will become a means of racial deterioration.

To summarize:

1. It is a law of the biological world that unused organs become parasitic upon the life, draining off the energy of the individual and tending to become diseased.

2. It has been found that physical culture which leads to the hypertrophy of special muscles, entails a drain upon the general vitality. As in life in general, so in physical education, organs that can perform no adequate function are wasteful of human energy.

3. Experimental psychology is showing that the culture of particular intellectual organs and functions can not be transferred to other organs and functions, except where there are elements in common. Histology and pathology of the nervous system confirm the conclusions of psychology in this respect.

4. Intellectual culture not being transferable must become parasitic and a cause of mental disorganization when it fails of application and usefulness in the life of the individual. Illustrations are to be found in the over-refinements of culture in academic communities, in the nervous instability frequently met with among educated men and women, and in the religious and social vagaries and perversions that crop out in the older and more highly cultivated centers of population.

5. The artificial culture of the secondary schools and colleges in our democratic society, in proportion as it is diffused throughout larger sections of our population, is likely to develop a cultured proletariat, ill-balanced and inefficient as individuals, and a source of danger in our civilization.

CENTRALIZED AUTHORITY AND DEMOCRACY IN OUR HIGHER INSTITUTIONS[1]

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IT is somewhat embarrassing to appear on a program that I myself have assisted in devising. It demands an explanation. It is, in short, an instance of too highly centralized authority in this association in the hands of our lively general secretary. It seemed eminently desirable to the committee that this topic to which I am to address myself should have consideration. When the first draft of the program came into the hands of the secretary, with a blank left after this topic, he rashly placed my name after it, rushed to print and scattered it broadcast over the country. So I am here against my will but, I must confess, not wholly reluctantly. The topic is of immense importance. It was a vain endeavor to find the proper person who should address you on this theme. All presidents and all who aspire to such position of power were condemned to silence from the start. That cut off the flower of the genius of the nation at a single stroke. The presiding officer of our department had an intimate way of knowing that presidents, being under indictment, so to speak, could not be trusted with the topic. There has been much written and spoken latterly on the theme, but mostly by those whose ambition has been punctured, whose pride has been stung or whose wings have been clipped. Were any of these turned loose in this place, they might enact a bloody scene not entirely consistent with the proper spirit of a *religious* association. Our general secretary must have known that I had no ax to grind, no grievance to right, no power except the power of righteousness to fear, and that I should speak in a wholly guileless manner. It is a temptation to admit that this was another instance of his rare insight; for however much my judgment may be at fault and wisdom limited, I shall address myself to this most delicate topic entirely without animus. I might follow the example, indeed, of one of our periodicals which recently declared that, with a single exception, theirs was the only sheet in the nation that is not subsidized. If I lay claim to being, with but an exception or two, the only mind in the nation that is dispassionate on this question, then every member in the audience will congratulate himself that he is that other person and we shall all be thinking through the subject helpfully to one another.

[1] Read at the meeting of the Department of Universities and Colleges of the Religious Education Association, Nashville, March 9, 1910.

There can be no question that American universities and colleges are highly centralized in respect to their organization and control. The power legally is in the hands of some kind of a board of education, mostly composed of business and professional men who are in no sense organically a part of the institutional life of the university. Practically, the power centers in a president and faculty. In all matters that refer to the running of the institutional life of the place, these are autonomous bodies. They make their own laws; set their own standards; inflict their own penalties, and exercise their influence without asking anybody any questions. Their constituency, so to speak in state and church has little power. President and faculty are considerate of their constituents—sometimes tenderly so, when the budget is in excess of the available means, or when the normal percentage of increase of attendance is not attained. Otherwise these good people are expected to be silent well-wishers. Perhaps that is as it should be; at least I see no way to change it. Our chief consideration at this time, however, is that *students* have almost no voice in the control of the institution they attend, little feeling of responsibility for its destiny, almost no sense that their personalities are caught up into it, or that they are an organic part of its best life. The ordinary student feels himself to be an attaché, a recipient, an appendage at best, and lucky for him if he is not a sort of parasite—a foreign body, drawing vitality from the institution for a time and then going away with it. If I am right in believing that the ordinary student has a sense that he is a sort of inmate of the institution, who must obey the rules and get what he can; who does not have a stimulating sense of partnership in the place; who can talk with zest about *my* fraternity or *our* team, but who never can talk with the same warmth about *our* college spirit, or *our* curriculum, or our faculty, or our institution; if the bulk of students at the end of the four years' course have any feeling deep down that the center and core of their own wills are aloof from the deepest, warmest currents of the institutional life, then something is wrong; for the university exists solely for the student—indeed, it has no other reason for being. I fear, however, that our universities have become bulky institutions that exist chiefly for themselves—to perfect their own machinery, to preserve their own lives; they are closed systems busy with inner adjustments, rather than with the problem of how they can cultivate the soul-life of those entrusted to their care, and burning with a passion to be of service, through the students, to church, state and humanity. Our higher institutions have been developing, during recent decades, rapidly in the direction of an imperialistic attitude toward students. Professor Stratton, who first set our minds going in a lively manner in this direction, points out the anomaly existing in our political ideals and our university practises, and also the anomaly of anomalies that

Germany reverses the inconsistency, being politically imperialistic, but educationally democratic. Speaking of our own nation he says:

> Among a people so jealous of private rights, university governments have assumed a form that we might have expected to see in a land of kings. European universities have a constitution that might have come from some American theorist. American universities are as though founded and fostered in the bourne of aristocracy. Europe and America are each harboring what would seem properly sacred only to the other.

There are four or five causes that have brought about too great a centralization of authority in the hands of president and faculty, and along with it a cleavage of interest of faculty and student body until they stand off from one another in a relationship that is not wholesome for either.

1. In the first place, a historic strain of autocracy has come down from the old-fashioned schoolmaster. In the early days of America, the schoolmaster, with rod and rule if need be, usually a man—not a lad of eighteen or a woman or much less a frail girl—was a monarch in his realm. He was built, and for a reason, on the lines of a sturdy, stern Anglo-Saxon father. He has left us as a heritage his custom and conception of imperialistic authority in education along with his ineffaceable three "r's." The secondary schools were differentiated from the common schools. The "head master" developed out of the parent stem, the schoolmaster, under the rule that like produces like. He was well named, for he was expected to be superior in wisdom and masterful in bearing. The college is a specialization of the old academy and high school, and has inherited from these many of its ideas about curriculum, form of organization and centralized authority.

2. In the second place, as Professor Stratton has pointed out, our higher institutions have received a strain from the form of government of the early colonies. These were under the rule of the mother country, which rule was effected through a corporation, or a governor, or both. They were never elected by the colonists nor selected from among their number, but superimposed on them from the mother country. Our boards of education are descendants of the early corporations, and the university presidents are built after the pattern of the early governors.

In imperialistic Europe the democratic life of the faculty and the university generally, on the contrary, is the direct historical consequent of the old guilds that were established around the idea of equality, fraternity and mutual helpfulness.

3. In the third place, the higher institutions have reaped the blessings and also the ills of the naïve democracy in which each individual is turned loose to do as he pleases, and, being human, chooses to be unduly self regardful. There are many indications that the earlier colleges, established by people whose passion was for equal opportunity,

incorporated unconsciously and as a matter of course, much of the spirit of democracy into their organization. The spirit of common fellowship often pervaded the life of the faculty and students. They were intellectual brotherhoods like families or fraternities in spirit. The gradual, quiet transformation that now has made of them, perhaps, the most imperialistic educational institutions in the world is not so difficult to account for. This has been a land of freedom and opportunity. There have been all kinds of things lying around loose in America—virgin soil, virgin forests, virgin mineral lands, virgin society and virgin politics. The liveliest and strongest have gone after the benefits, appropriated them, taken means to hold possession against the covetous, and then, alas! have found themselves unwittingly, as a result of wealth, social preferment and political power, proud, arrogant and irresponsible, and pitted against their fellows. Those who have not been lucky themselves have nevertheless had something of hero-worship in their veins. They have admired Napoleonic success and Anglo-Saxon strenuousness. They have passively paid tribute and so have had their part in the immoderate inequalities that have sprung up. The inevitable outcome of it all has been a harvest of captains of industry, captains of wealth, captains of politics and captains of education.

Do I dare say aught in this place about college presidents? If so, it would be in the "spirit of sweet charity." They have had their temptations and trials; they are subject to weakness of the flesh; they have been battered and buffeted, and whatever is said about them must be spoken in kindly sympathy. They are not vicious, they are not "exploiters of genius"; they are not worshippers at the shrine of mammon, nor devotees of the God Thor with his symbol of the arm and hammer; they are just human. Like all of the other citizens in our primitive republic, with its free opportunity, they have seen a good many things lying around loose. This time it has not been some irrigation stream or mineral deposit that they saw lying unclaimed, but the opportunity for power. No one else had been exercising it, and why not they? Indeed, they have gathered of the treasure in large measure, and why not? Men do love power if they are normal. There is no better thing in the moral order than a will that can produce, create and help things along. There is not a more righteous joy than the feeling of that fine tension of a strong will that can be a living force in the world. But enough is a sufficiency, and too much, even of a good thing, is dangerous. And men are human. Let us say, with gracious compassion, that it is the fault of the times, of our social order, that has placed in the hands of presidents the power of life and death over the professional career of members of the faculty and also the shaping of the destinies of our educational institutions.

Members of faculties are also human. They have acquired all the power that has been relegated to them by constituencies and boards of education, and have picked up whatever else they could acquire on their own account. They have sometimes watched their chances to share the responsibilities of the institution with the president, lest it should weigh too heavily upon him. Some one has happily said that no Irishman could be found in Ireland so poor but that he has not some other Irishman dependent upon him. Presidents and faculties together have come into the position of almost entire separation from the student body. They have the attitude of ruler and ruled. They march in stately parades, begowned in robes of dignity and state before the admiring eyes of the students; they run the institution; they dispense grades and degrees as parsimoniously as possible to students who devote their college career to earning these marks and badges as economically as possible.

4. In the fourth place, competition has played its part in bringing about centralized authority. It has been necessary for institutions to act and act quickly in the raising of funds, in the employment of instructors and in appeals to the public. The matter of winning out in the contest has led us to do much as a hive of bees in creating a queen. We have done everything in our power to produce presidents who are masterful, who can appear well, who can be "drawing cards" in tempting into our institutions the guileless youth of the land. There is no one who will dispute that our university and college presidents are of the noblest of our people. But we are creating them at too high a cost. It is the fundamental axiom of our entire educational system that the end is not so much to produce leaders as to lift the level of all. It is growing too late in the history of democracy in the world to need to argue the point. Still an analogy will be in place. Christianity, during the first century, was a spiritual brotherhood. In the second and third centuries, they began to have conventions, and it was the custom for a bishop and at least one layman to represent a church or diocese. By the fourth century, the laymen had been almost forgotten in their councils; and from that time on the power became more and more centralized in the hands of a few of the highest officials of the church. The consequence is a familiar fact of history. From the fifth century, for several centuries following, the organization of Christendom was a closed system with neither change nor progress. It existed not for mankind as persons, but for itself and its own institutional ideals. In our educational system the laity, the students in our universities, have long since lost their voice. Our educational elders, let us say, that is, members of faculties, have been little consulted in our national association of universities that are taking upon themselves the right to determine the educational policies of the country. We are living in a

later age, and must not allow the history of the first five centuries to repeat itself.

The spirit of competition has magnified out of all proportion the value of quantity instead of quality. Bigness has bred looseness of organization and aloofness of person from person and group from group. The tendency toward manifoldness has been augmented by the natural law of differentiation, of which specialization is an instance, until our institutions are atomistic. Each person has relegated to everybody else all responsibility for everything except his own little sphere of interests. This differentiation amounts in the long run to radical individualism and approximates indifferentism, the worst disease that can affect the life of higher institutions. The only excuse for the large university is that it may have a more highly organic and intense life than a smaller one can have. Growth at the expense of inner coordination, refinement of articulation and intensification of the individuality of the whole, is a disease, whether in plant, animal or institution. We have grown like a boy in his teens as fast as our health would allow. The rapid differentiation in general has naturally widened the gap between student and faculty, who are made for each other like eyes and hands. The next step, in order to get safely through our stalking educational adolescence, must be in the direction of binding up into the life of our colleges again, the personal lives of students.

5. Still another fact must be mentioned that has made of our faculties against their own will, ruling or governing bodies who are set off against a pack of persons supposing themselves to have antithetical interests to those of the university as an institution. Through the hasty expansion, already referred to, the machinery of the university—teaching, looking over papers, grading, giving credits, establishing standards, etc.—has grown into such proportions that there is little time and energy left for anything else. The enforced result is that the prevailing point of contact between students and instructors has come to be in terms of their proper advancement and grading in the curriculum, and what they must and must not do while resident in the institution. I appeal to those present who have spent a number of years as instructors in colleges and universities whether nine tenths of the time of the faculty meetings is not given up to such questions as marking systems, giving of grades, granting degrees, penalties for delinquencies, admission and classification of students, control of athletics, regulation of social affairs, and the like, which have nothing to do, except indirectly, with the inner personal life of students. From the University of Plato in Athens, Plotinus in Rome, Abelard in Paris, and the College of Mark Hopkins in America, we have traveled far. We catch glimpses in the New England days of what was called among professors, a hunger for the souls of students. Those days will never

return; but we have suffered a loss that is irreparable, if there is not preserved in our colleges and universities the equivalent of the things they did, as shown in reverence for the divine beauty of personality in the lives of our students.

There can be no question but that our attitude toward students is conventional, mechanical and institutionalistic. Behind us, to hold us firmly in our chosen course, besides the causes we have been describing, is the wish of anxious parents who forget that their young men and young women are not still children and who say gracious things about their favorite institution if their sons are held in check, and if their daughters are tenderly "guarded" and pampered.

What are we to do about it? How can the student body and faculty be brought into closer relationship? How may our universities escape a cold institutionalism? What changes will move in the direction of most surely catching up the personal loves and enthusiasms of the average student into the warm, vigorous, purposeful life of the institution? There are many things to do, certainly. I shall confine myself to a simple urgent suggestion that leads, I believe, towards the heart of the situation. The spirit of democracy should prevail. Not a sentimental democracy that preaches equality and cooperation, and practises autocracy. *Students should be given a part, however small, in the control of our institutions.* It is not my purpose to determine specifically what their powers should be. That has been so delightfully and convincingly discussed in the paper preceding my own that nothing further need be said. It is in itself a suggestive fact that Professor Fiske, like every one I have met who was connected with the Amherst attempt at self-government, believes in it thoroughly. Indeed I know of no one who has observed intimately any of the various experiments in student participation in student affairs, who has for it other than words of commendation. My contention would be that the kind of thing students undertake is more or less indifferent, if only they feel that it is worth doing and that they do it with a will. It may be the matter of honor in examinations. Students can do this successfully, as several happy instances prove, while instructors are powerless to cope with it, except at a cost in moral and social attitudes toward students that is hopelessly disastrous. Let it be the regulation of social activities, over which faculties distress themselves and still do their work so bunglingly that students wink at it and smile at their own cunning. In some institutions students have undertaken the control of the daily paper, monthly literary sheet, and a comic sheet, from which they learn the meaning of free speech and the virtue of controlling it, derive lessons in collective ownership and the joy of building for the future. In some instances they have been given a controlling voice in athletics, with advantage to the spirit of the institution. One spontaneous

impulse of students toward pure sportsmanship that grows out of facing a concrete situation with responsibility is worth a half dozen lectures by a professional moral dictator. These are only instances of the many possible lines along which student activity may express itself. President Drinker, who has, with remarkable success, encouraged self-government at Lehigh University, says: "It has been my experience that the more responsibility is placed upon students, provided they are willing to assume it, the better it is for all concerned." Even a small duty that students enter upon heartfully is enough to transform their attitude into one of partnership. It is an old rule that interests follow activities as the shadow the body. Sympathies and enthusiasms apart from deeds are pale and shallow. When students undertake anything in concert they must have organization. This creates unity of action and solidarity of sentiment. The fact of positions of emolument to be filled and the need of officers, leads to college politics with its fine tension of rivalry and its tang of victory and defeat. Let us grant there will arise occasional abuses and mistakes. There are instances on record. The number is, however, relatively small. The redeeming feature of it is that whatever failures and successes they make, there is in it a preparation for citizenship. They are meeting in college life exactly the problems and difficulties that they will have to face later. We preach the gospel of learning to do by doing in the lower grades of our common schools, but are full of the notion of the value of learning to do by obeying, during the choice years of young manhood and womanhood, which are above all others the time for preparation for the duties and responsibilities of citizenship. The educational world has had its prophets this long time of the value of social and family ideals among tiny children; but by a strong irony of fate, we have been slow in taking seriously the same problem during the critical formative years of a college course.

The root of the difficulty is in the need of more democracy in our institutions. That would come in a day if all concerned could apply the golden rule. There is a sort of mental near-sightedness in human nature by which it is hard to see through the other person's eyes and feel his problems. All are, furthermore, intensely human—biologically human—and want all they can get of power and prestige. Universities have differentiated into about four types of personages: a board of education, a president, a faculty and a student body. All except the last would dominate everything if it could. The best results will come only when each participates slightly in the whole, but specializes upon its own function. The board are specialists upon finance and should exercise a fairly free hand in all the material interests of the university, with only a negative control, through the power of veto, upon scholastic affairs. The faculty are specialists upon institutional questions. All

matters of the formation of the curriculum, standardization, election and dismissal of instructors and the like, belong naturally to the faculty, with board and student representatives, under normal conditions exercising advisory influence. It is as hazardous for boards of education to assume responsibility for the complicated institutional life of a university and exercise the fine shades of judgment needed for its success, as it would be for the ordinary university professor without the requisite years of preparation to run a bank or department store. The president should be chairman of the faculty. His proper function is primarily an executive one, and in no sense legislative or judicial. But the prerogatives of students—what are they? I recently asked a professor in a state university what power, in his judgment, students ought to have in an educational institution. He replied, "Power? Why, the *power* to work and work like thunder." When I argued that they were already in possession of such freedom, he retorted emphatically, "But they do not seem to know it!" No one has to urge a graduate student, interested in his problem and inspired by personal contact, to work. Usually, on the contrary, he must be restrained from too continuous application on account of his bodily health. His attitude toward instructors, tasks and institution is different. Student bodies have rarely come into possession of their own. Why should they not have full responsibility for student enterprises and social activities? How much power of the faculty, which is legally the responsible agent in such matters, should be in evidence, is an open question. Professor Payne, of the University of Virginia, where for more than a century students have successfully regulated questions of student honor, honesty and propriety, assures me that the plan is working well, just because the faculty keep their hands off entirely. Under such circumstances students are glad to regulate their own affairs, and they do it well. I know of no instance in which students have participated in the activities of an institution, wherein they have broken faith or usurped power. Still they are treated as underlings, while instructors keep school, hold examinations and administer grades. Under present conditions they are filled with ideals of military discipline rather than infused with social impulses. Why may not our universities be transformed into states in miniature or social communities, in which students are "the people," each of whom is tempted by the entire situation, to care, to lend a hand, to feel the thought currents of the time, to know men as well as books, to be efficient units in society? In this direction we must tend if our new ideals of social righteousness are to be woven into the texture of our common life.

The problem would be easy were we not tempted by the luscious sense of power and blinded by a highly developed institutionalism. The university exists for the students, and not the students for the university.

No one would care to depreciate the conservation of race life that is accomplished through the mere fact of the existence of a group of teachers, a body of college customs, and well-equipped laboratories and libraries. But they are not finished products. They are means to an end in a living, growing organism. The end is the best life of all and the fullest life of the future. There is a distortion when the rich inheritance of the past that the university represents is not directed wholly and purposefully toward the students who are to be the race of to-morrow. To this end the university may well exert itself to have them feel that they are organically a part of it. Each student when he goes out should be, not a recipient from the institution, but a real incarnation of its best life. He must be in it and of it. The form of organization should tempt him into closer and closer heart relation with his school. Let it not be, either, a seeming act of charity or missionary enthusiasm on the part of instructors, or the best is lost. The advantage is mutual. Each student has some original endowment from nature to bring to the institution. I have heard it sometimes expressed that part of the fascination of the life of a teacher is in the personal enrichment and the multicolored quality of truth that come from mingling with many types of student minds when each is allowed to be at his best. In order to bring out the riches of his nature, generally as yet undiscovered even to himself, the attitude of the university toward the student and his attitude are almost everything. It can not reach him from the outside in; it can inspire and educate him only from the inside out. Let our universities be decentralized from their organization about institutionalism, and recentralized in the personal lives of students.

THE FIVE-FOLD FUNCTIONS OF GOVERNMENT

By W J McGEE, LL.D.

I

ORGANIZATIONS, like organisms, are products of development. Governmental organizations, like most others, are increasingly designed and shaped in the light of conscious experience. Thus, the constitution of the United States epitomized the lessons of history so far as recognized by its framers, whereby the instrument became the embodiment of governmental practise and theory gained through known experience. Naturally, by reason of the ability of the framers and the stress under which they wrought, the instrument is notable—certainly among the most notable ever produced, whatever be thought of Gladstone's view as to the divinity of its inspiration. Naturally, too, the framers specified most clearly those governmental powers with which they were familiar and which they most desired to adopt: and, no less naturally, their action was guided quite as much by the wish to eliminate that which they thought objectionable as by the aim to perpetuate that which they deemed desirable. Seeing that government is an expression of law, their first care was to provide for the framing of laws, the second to provide for the execution of these laws, and the third to provide for the interpretation of law; and in this way arose what came to be known as the "three coordinate branches" of the United States government. The branches are indeed coordinated, though they are far from coequal, since the power of creating the third is entrusted to the second "by and with the consent" of a part of the first; yet they by no means constitute the entire government—as becomes clear in the light of earlier phases of social organization made known largely since the instrument was framed, no less than in that of discussion before and during the framing of the constitution.

Early in that primitive social type in which tribal organization rests on consanguinity traced in the female line, the elder-woman is both lawgiver and judge, while her elder-brother acts as an executive in case of need, and the two jointly or severally exercise administrative authority throughout the clan; later the elder-women become priestesses or seeresses still giving and interpreting the clan laws, and their elder-brothers form an avuncular council of gradually increasing executive and administrative powers; yet at every step all primary power is imputed to a mystical pantheon of which the beldames are only vicars and the sages merely indirect agents. In the next stage of development

(*i. e.,* in the patriarchate, in which organization rests on consanguinity traced in the male line), the elder-man becomes vicar or priest, and hence law-giver and judge as well as both administrative and executive —as when a patriarch communes with his deity over sacrificing a son or daughter, or a kalif commands of his own impeccability, sits in judgment, awards and rewards, imposes and deposes, and (like a later emperor) personifies the state; yet his primary power is imputed mainly or solely to that supernatural source of which he is deemed but the agent. With the growth of cities and those civic usages in which the organization arises in proprietary right (especially in lands), rulers long remain vicars of mystical or spiritual powers manifested in symbols and ceremonies though often exercised through arms and armies; and until within recent centuries each monarchy was virtually a hierarchy whose king or emperor stood—panoplied in the "divinity which doth hedge about a king"—as the source and exponent of both temporal and spiritual power, performing so much as he would of all governmental functions, his rule ranging from hierarchic to autocratic according to the faith and custom of the time. Gradually (the rate being vastly accelerated by the American Revolution) the monarchs surrendered legislative functions, delegated judicative powers, divided administrative and executive duties with the agents of parliaments and courts, sometimes shared their vicarial powers with ecclesiastic potentates, and began yielding to the inevitable growth of petition into suffrage; yet no monarch was ever quite independent of putative supernatural powers residing within or conveyed through his own personality, or of the symbolism or ceremonial tending to perpetuate the imputation.

In brief, during each stage of governmental growth from the simplicity of primal clan to the pomp and circumstance of gilded empire, the primary functions remain much the same despite sweeping changes in structure. In logical order the functions are (I.) initiatory, and (II.) directive, the former connoting the source and the latter the aim or control of institutional power. In genetic sequence, or in that order of successive manifestation illustrated, *e. g.,* in the natural family of which the clan, gens, city and nation are outgrowths, they are (1) *administrative,* or concerned with the current regulation of every-day affairs; (2) *legislative,* or concerned with the establishment of rules of conduct (always finally adopted only through common consent); (3) *judicative,* or concerned with the peaceful settlement of disputes in accordance with custom and established rules; (4) *executive,* or concerned chiefly with the carrying out of rules and judicative decisions; and as the natural source of power gradually comes into ratiocinative view in the light of the general good, (5) *determinative,* or concerned with the primary expression of common judgment and desire.

Now when the founders of the American nation undertook to frame

a governmental organization, little was known of the natural stages in the course of human development. The notable works of Maine and McLennan on primitive law, of Fustel de Coulanges on "The Ancient City," of Lewis H. Morgan and Herbert Spencer and Auguste Comte on early society, and of Taylor and Powell and Brinton on lowly religion had not been written—indeed the epoch-marking investigations of these and other writers run back to the unprecedented efforts of the American revolutionists to ascertain the ultimate foundations of human government, efforts not disparaged but only accentuated by the rapid growth of human knowledge since they were made. Since then, science has come into being on the earlier foundation laid by Bacon and Linne and a few others: of the five cardinal principles of science,[1] the first (the indestructibility of matter) was established by a contemporary of the Revolution, Lavoisier; the second (the persistence of motion) grew out of Rumford's experiments begun under the influence of this American rennaissance; while the others (the development of species, the uniformity of nature, and the responsivity of mind) came scores of years later—indeed nearly all of the current branches of science have arisen since the revolution. Since then, too, historical knowledge has been both expanded and refined; geographic knowledge has extended over the full half of the earth then practically unknown; invention has revolutionized industries, largely through the American example; steam and electricity and high explosives have been harnessed; the world's population has doubled; man's conquest over nature has advanced further than during all earlier time; statecraft in the modern sense has taken form, and diplomacy has been reconstructed, both largely through the world-touching influence of the seventh and eighth decades of the eighteenth century; and the American governmental model has been adopted in spirit if not in form by far the greater part of the nations of the earth. In the light of the vast advance since 1776, the sagacity and courage displayed by the signers of the declaration and the articles of confederation, and especially by the framers of the constitution, shine forth among the greater marvels of human history.

The founders included eminent scholars and statesmen, yet they were practical men confronted by problems of which the issue meant life or death; and on surveying the field of experience in governmental organization within their reach, they seized on the essentials and wisely withheld their hands from both the collateral and the controvertible. Dwelling long on the pressingly practical (as shown by the record of discussion in the constitutional convention), they defined clearly the legislative and executive and judicative functions of the nascent gov-

[1] Outlined in an address of the president of the Anthropological Society of Washington, delivered before the Washington Academy of Sciences and affiliated societies February 19, 1900 (*Proceedings of the Washington Academy of Sciences*, Vol. 2, 1900, pp. 1–12).

ernment, leaving the then relatively unimportant details of administration—over which controversy arose whenever the subject was approached—to the sense of their successors; while they proceeded so circumspectly as to reveal implicitly rather than by explicit statement their chief—and history's greatest—contribution to governmental principle, *i. e., the substitution of human power exercised through an electorate for the inscrutable might manifested through a hierarchy* as the basis of government. Strong as is the constitution in every feautre and department, its chief strength lies in that last-written but first-placed paragraph, "We, the people of the United States, . . . do ordain and establish this Constitution." With this utterance the mysticsm of the ages fell away, and the foundation of humane government became fixed forever; and the new light has already gone around the world and entered every land.

Now in addition to the specific powers expressed in the first, second and third articles of the constitution, others are so clearly implied or expressed *inter se* that they were unhesitatingly exercised from the day the instrument was adopted. These embrace the administrative power implied throughout, together with that primary power ranking all the others combined (since they rest on and arise from it), *i. e.,* the determinative (or elective) power implied in the first, second, fourth, fifth and sixth articles and expressed in the preamble. So any complete enumeration of the powers of our government (or any other of representative type) necessarily comprises those pertaining to the five innate and coordinate functions involved in all governmental organizations from the most primitive to the most advanced; in logical order—which is that reflected in the constitution—they may be denoted (1) *elective,* exercised by the people; (2) *legislative,* exercised by the congress; (3) *administrative,* exercised by the president and his cabinet officers; (4) *judicative,* exercised by the court, and (5) *executive,* exercised primarily by the president.

II

The popular movement for the utilization of our waterways[2] first marked an awakened public sentiment; now it is stirring the national conscience in a manner not unlike the movement of 1776. A round century of public indifference since Gallatin followed Washington in pointing a way, and a half-century of national incompetence attested by the decline of river and canal navigation—these unwittingly set the alarm now ringing. As befits democracy, the awakening began with the extremities of the body politic; yet signs are not lacking that it is reaching the somnolent centers. When the declaration and the con-

[2] Described in "Our Great River," *World's Work* for February, 1907 (Vol. XIII., pp. 8576–8584), and "Our Inland Waterways," POPULAR SCIENCE MONTHLY for April, 1908 (Vol. LXXII., pp. 289–303).

stitution were framed, the sense of citizenship still lay dormant in all but a few leading minds, and in some of these soon turned sluggardly for longer slumber; then the legion prodigals were fed with the swine on husks of party welfare rather than the sound corn of public weal until a shadowy "no-man's-land" grew up between citizen and state and a "twilight zone" spread between state and nation. Yet, stirred at last by the waterway movement and a forest policy uniting in the cult of conservation, the people are at last preempting the shadowy middle ground, and thus coming into their own as citizens. Two years ago the governors—the actual sponsors for the welfare of their commonwealths—felt the stir; they responded vigorously, and now they and their people are moving together against a tyranny of regnant apathy not greatly different from that of his ease-loving and privilege-giving majesty George III.

Within a few months the congress began to respond to the popular demand by authorizing the publication of the reports of the Inland Waterways Commission and National Conservation Commission and the Proceedings of the Conference of Governors; then the senate created a strong committee on the conservation of natural resources; and within a month this committee reported favorably a bill for the establishment of a "National Commission for the Conservation of Natural Resources." The report[3] meets the popular movement half way. Declaring that "The measure is designed to conform with various actions, both legislative and administrative, growing out of one of the strongest popular movements in the history of our country," the document outlines the movement, summarizes the nature and extent of our natural resources, indicates the leading wastes and the industrial diversions attending development of the resources, and concludes with a plan for action framed to meet the people's will. Even more significant than the body of the report is the appendix; for at last the senate has yielded to the voice of the people sufficiently to print the expressions adopted in great conventions of citizens—among others, the declaration of the Fourth Deep Waterway Convention (adopted in New Orleans November 2 last) "comprising duly appointed delegates to the number of 5,000 from 44 of the 46 states of the union, including the governors of a majority of the states," which finally turned over a new leaf by recognizing and declaring the rights of citizenhood to "demand and direct" action by their representatives—in lieu of the far lesser rights of subjecthood to "petition" or "submit" or "respectfully request" or "forever pray" with which Americans have been content for a century —and then nailed down the new leaf by the public pledge of personal honor proper to full citizenship! Surely if these 5,000 delegates mean

[3] Calendar number 733, Sixty-first Congress, second session, Senate Report No. 826, pp. 1–50; ordered printed June 11, 1910.

what they say—and who can doubt their sincerity?—no more significant utterance has been made on American soil since the declaration of July 4, 1776. The final paragraph of the declaration reads:

> **Believing in our hearts that the needs of the country and the fundamental principles of our government set forth herein involve moral no less than material issues, and agreeing that the time has come for us and the other citizens we represent to exercise our constitutional powers by the means provided when the constitution of the United States was framed, we, the delegates in this convention assembled, representing more than half the people and three fourths the productive energy of the United States, do hereby deliberately and firmly, and in the full realization of our duties and responsibilities, demand and direct that a definite and vigorous policy of waterway improvement, beginning with the Lakes-to-Gulf Deep Waterway, be adopted and put into operation by the national government without delay. To the enforcement of this demand we pledge our individual effort and our united support; and we hereby publicly pledge our personal honor, each for himself and to each other, to support no candidate for public office who will not unqualifiedly indorse and maintain that policy.**

Academically, such an utterance is in so full accord with the constitution and with the principles of popular government as to be commonplace; yet actually it is so far out of accord with current governmental methods that the third of the representatives and senators in attendance at the convention generally (except perhaps a dozen progressives) repudiated and condemned the utterance more or less openly as "socialistic" or "anarchistic." Still the voice of the people has echoed and reechoed; and at last it has reached print in a public document.

The spirit of the Lakes-to-the-Gulf Deep Waterway Association expressed in their declaration has cropped out in various conventions other than those noted in the senate report. During the past two years the question has been growing more and more incisive, Is this nation competent to protect the interests of its people? The question has been pressed in non-partisan assemblies held in every section, including citizens of every state, and with constantly increasing directness and pointedness; and it is a sign of the times that it is put with a sense of power and a realization of responsibility unprecedented in the century and a quarter since Washington moved toward the constitution. America—the collective mass of ninety million souls—is a long-suffering if not lethargic giant, slow to wrath and show of strength; yet as to its power when aroused—who can doubt? Its full strength lies in the spirit of the ninety millions; the force of a first effort lodges in some eighteen million voters, a half temporarily tied by one special interest or another—but nine millions are full freemen, and five millions more are ready to follow their lead. Now that the giant is aroused, in conscience no less than in sentiment, the demand of the people is attracting attention. Already the waterway advocates can point to a partial re-

sponse to their demands in enlarged provision for river surveys, in provision for a national waterways commission empowered to extend and apply plans framed by the last administration, and in a recent declaration of the administrative and legislative authorities that "pork-barrel" appropriations must cease—indeed, to the longest steps in the right direction since Washington previsedand Gallatin planned and Windom pleaded for rational waterway development. Verily, the waterway workers have not wrought in vain!

The significant fact lying behind the past and prospective legislation is the power of the people when once aroused—a power not to be confounded for a moment with that of tumult or mob, but inhering in the very spirit and lodging in the innate structure of democracy. True, this power is too often ignored by those for the moment responsible for the public welfare, too little felt by its own possessors; it is seldom stirred save by war or rumors of war, rarely tempted to exercise save by partisan calls at times of political stress; yet although a virtually neglected factor of our national life, it is worthy of weighty consideration.

III

The first, second and third articles of the constitution, respectively, define the legislative, the executive (including the administrative) and the judicative functions of the government. The specifications of the executive function are general to the point of vagueness—naturally enough, in view of the then current antipathy to concentrated authority. Few matters were so faithfully discussed during the constitutiontl convention as the powers of the president;[4] and few of the discussions better exemplify the superlative caution which constantly led the delegates away from definite specifications and toward bare generalities in compromising mooted points. So, just as the instrument is silent on the primary governmental function save in the preamble, the commonplace functions of administration are implied rather than explicitly stated in the second article—being most clearly (or most nearly) defined in the oath or affirmation by the president-apparent that he will "faithfully execute the office of president," which "office" manifestly covers minor governmental affairs not otherwise specified. The indefiniteness was not due to inattention or indifference concerning the administrative function, as the debates clearly show. Mid-course of the deliberation, "Mr. Gouverneur Morris" thus expressed what seems to have been a prevailing view:

> One great object of the executive is to controul the Legislature. The legislature will continually seek to aggrandize & perpetuate themselves; & will seize those critical moments produced by war, invasion or convulsion for

[4] The index to the discussion occupies a page in the recent edition of "Madison's Journal" (edited by Gaillard Hunt; Putnam's, New York and London, 1908).

that purpose. It is necessary then that the Executive Magistrate should be the guardian of the people, even of the lower classes, ag^st. Legislative tyranny, against the great & the wealthy who in the course of things will necessarily compose the legislative body. Wealth tends to corrupt the mind to nourish its love of power, and to stimulate it to oppression. History proves this to be the spirit of the opulent. The check provided in the 2^d branch was not meant as a check on legislative usurpations of power, but on the abuse of lawful powers, on the propensity in the 1^st branch to legislate too much to run into projects of paper money & similar expedients. It is no check on legislative tyranny. On the contrary it may favor it, and if the 1st branch can be seduced may find the means of success. The executive therefore ought to be so constituted as to be the great protector of the mass of the people. It is the duty of the executive to appoint the officers & to command the forces of the republic: to appoint 1. ministerial officers for the administration of public affairs. 2. officers for the dispensation of Justice. Who will be the best judges whether these appointments will be well made? The people at large, who will know, will see, will feel the effects of them. Again who can judge so well of the discharge of military duties for the protection & security of the people, as the people themselves who are to be protected & secured?[5]

Unhappily, the indefiniteness begat uncertainty, which has multiplied with the growth of the country; for public affairs requiring administrative attention tend to increase geometrically (just as do transportation lines) with the number of individuals and communities touched. Under the natural desire to protect prerogatives (so clearly foreseen by Morris), and with a facility due to the weight of numbers, the congress gradually grew inattentive to the first duty of the president under the constitution ("He shall, from time to time, give to the congress information of the state of the union, and recommend to their consideration such measures as he shall judge necessary and expedient"), and drifted into the habit of obtaining "information of the state of the union" by more cumbrous methods directly through their own committees or indirectly (and of course unconstitutionally) from the administrative departments. Moreover, they increasingly ignored the warning of George Washington (the presiding officer and moving spirit in the constitutional convention) in that ever-memorable farewell address read annually in their hearing: "Let me . . . warn you in the most solemn manner against the baneful effects of the spirit of party generally. . . . The alternate domination of one faction over another, sharpened by the spirit of revenge natural to party dissention . . . serves always to distract the public councils and enfeeble the public administration"—so that the nominally representative congress has virtually ceased to act in behalf of the people and come to act instead in behoof of party, in ways for which no shadow of constitutional warrant exists. It would appear that the gravest apprehensions of Washington and Morris have been realized in a policy of special legislation so pronounced that—mirabile dictu!—fully 99 per cent. of the bills

[5] *Ibid.*, Vol. II., pp. 1–2.

introduced during an ordinary session are special, local or personal in whole or in part, while far the larger part of the committee work and public debate appears to be devoted to special or local interests! Naturally little time and thought are left for general laws, touching alike the entire citizenry; and naturally the custom of special legislation under party control opens easy way for such machine organization that a half-dozen shrewd manipulators may assume leadership in either house and completely dominate legislation. So far has this tendency run that it is to-day a grave question—the gravest in our history—whether our current laws are framed in the interests of our ninety millions or in the interests of special privilege reducible in the last analysis to a scant dozen "captains of industry": and hence whether after all representative government is inherently and permanently stable. The "propensity" of the congress "to legislate too much" has indeed been checked from time to time in the manner forecast by Morris; for while some administrations acquiesce, others hold out for a stricter conformity with the constitution. George Washington sought to carry out the intent of the instrument framed under his chairmanship, and was so savagely assailed for "usurpation" that he declared death preferable to public service; Abraham Lincoln carried forward the administrative affairs of his terms through sheer force of personality, aided indirectly by the military activity of the time; no less competent authority than the present president of the United States once signalized Grover Cleveland's insistence that the presidency carries power coequal with those of the congress as *the* notable feature of his administrations; and Theodore Roosevelt's policy was consistently parallel and still more vigorous, even to his final and most trenchant presidential message pointing out the unconstitutionality of an item in the sundry civil act passed as his term closed. Meantime some heads of executive departments shrank from assuming administrative responsibilities; yet under growing necessity they have gradually become our chief administrative officers.

Verily the price of indefiniteness as to the administrative function in our fundamental law has been large! Not only have confusion and friction arisen, with enormous attendant expense, but the relatively simple duties of administration are ill-performed. The advocates of waterway improvement were among the first to notice that nearly all our waterway enactments to date are special, and tend to magnify rather than merge sectional and political interests; and that the flood of special bills and local items has so far diverted effort from general legislation that even unto this day the country lacks fundamental laws relating to waters, and is weakly perpetuating monarchial common-law doctrines not only unsuited to current conditions but such as the constitution was designed to annul or forestall! The waterway workers are no longer slow to condemn methods which have permitted—if indeed they have

not caused—the decline and disappearance of navigation from the finest river system of the world in a country suffering from the lack of transportation facilities. Already a majority of the states are moving, and many citizens in every state are astir; and the prevailing sentiment runs along the lines forecast century-before-last by Gouverneur Morris and George Washington.

IV

When popular assemblies "demand and direct" action relating to waterways, regardless of party and under a suffrage penalty, the awakening means more than mere recognition of bad legislative and administrative methods; it extends to that innate and primary power seized on by the founders as a substitute for the "divine right of kings"—*i. e.*, the power of the people defined in the preamble of the constitution and exercised through the suffrage. While this power has existed throughout our history, the act of suffrage is the last to be realized as essentially governmental—indeed as the supreme function of democratic government. The spirit of free citizenship arises slowly; to the anthropologist it is the latest self-conscious attribute acquired by mankind in that long course of human progress stretching from the prime to the present. Even in our Atlantic tidewater states, the real home of democracy, few citizens feel the franchise as in and of itself a function of government; in oratorical flights they hear and even declare that ours is a government of the people by the people for the people, yet only the exceptional citizen actually *senses* the casting of his ballot as a function no less governmental in character than those delegated thereby to his fellow-citizens acting as president and representative and judge. Now this is the sense stirred by the non-partisan waterway and other conventions, particularly in the newer states west of the Appalachians; it is the sense stirred as well in DesMoines and other municipalities governed by the commission system carrying provision for initiative and referendum and recall—the sense of innate *power* exercised through the elective function.

Concurrently with the sense of power the realization of rights is arising; and naturally enough, first as to the waters. Finding nation and most states apathetic, the more progressive waterway advocates looked into fundamental questions for themselves; and now, as a member of the supreme bench recently declared half querulously, "The country is full of constitutional lawyers." Five years ago, few citizens cared to consider the ownership of water in itself; to-day tens of thousands are familiar with the tenth amendment ("The powers not delegated to the United States by the constitution, nor prohibited by it to the states, are reserved to the States respectively or to the people"), and hold that since this resource was never granted to the nation or conveyed to the states it necessarily belongs to the people as a heritage no less inde-

feasible than the common title to sunlight and air, or indeed the equal rights to life, liberty and the pursuit of happiness; and three great conventions during last year adopted in substance the water plank made public by the senate committee on the conservation of natural resources.

We adhere to the principle arising in our constitution and incorporated in statutes recently enacted in several states that the waters belong to the people, and maintain that this right of the people is inherent and indefeasible; and while recognizing the necessity of administering this invaluable possession of the people by state and federal agencies, each within its appropriate jurisdiction, we deny the right of municipalities or of state and federal governments to alienate or convey water by perpetual franchises or without just consideration in the interests of the people.

With the sense of power and the realization of rights, the consciousness of duty is spreading. Until recently, provision for waterway improvement or other public works otherwise than by direct appropriation was commonly deemed chimerical; and citizens were led by advice of their representatives and the policy of congress to look on local appropriations as spoils of conquest rather than general contributions to the public good—whereby the "pork-barrel" was kept open and the appropriations went for "works" with little regard for actual navigation of the waters. Now, seeing that despite the expenditure of hundreds of millions on waterway "works" navigation of the rivers has declined, the people demand business-like methods whereby public funds shall be expended only for commensurate public benefits; and since the people have spoken, presidents, governors and probably a majority of the congress are concurring in the wisdom of issuing bonds to cover the cost of continuously and increasingly beneficial public improvements. Almost never before has the issue of bonds been contemplated without more or less open guarantee from Wall Street; but now legion citizens clamor for opportunity to share public burdens directly on a patriotic basis rather than indirectly through the expensive medium of special interests—for in the end the people pay. Under this pressure bills have already been introduced in the congress providing for waterway improvement on the basis of bonds issued in small denominations bearing interest too low to tempt bankers and brokers; and the adoption of this popular policy promises to mark America's most definite step toward making her citizens joint owners rather than passive tenants of their common country, and thereby at once raising patriotism to a higher plane and insuring stability of the nation.

The recognition of rights and duties respecting the waters leads to juster appreciation of other resources, which were of no account when the constitution was framed but have acquired value through the natural growth and orderly development of our population and industries; and to-day several of our forty-odd state conservation commissions hold that in legislative or other action looking toward wiser use and conservation

of the natural resources the people are but protecting their own. The growth of the sense of common welfare has been greatly impeded by court decisions based on common-law doctrines which the constitution was designed to displace, decisions sometimes tincturing later legislation; yet several courts have fairly kept pace with the growing sense of eternal equities among the people—they who adopted the constitution partly to provide a judicative mechanism adapted to their own needs and subject to their own supreme will: The decision of the supreme court of Maine that the public are entitled to a voice in the management of forests affecting stream-flow; the finding of the New Jersey court of errors and appeals, sustained by the supreme court of the United States, that the people have a residuary right in the waters; the opinion of the supreme court in the Rio Grande case that the government may maintain navigability by protecting the source waters—these and other decisions tending toward closer unity of interest among all the people are signs of the times. So, too, are the enactments by the congress for reclaiming lands and constructing canals under the "general welfare" clause of the constitution, and providing for the Panama Canal and for operations in the insular possessions under the same constitutional warrant—enactments viewed askance by ultra-strict constructionists, yet amply sustained by that court of final appeal, the judgment of the people expressed through their franchise and sustained by their own paramount power.

V

The waterway and conservation movements are still young, and may reasonably be expected to contribute continuously to that public welfare by which they were inspired. Whatever they may do in the future, they have already done much. They have revealed to the people a growing sense of their own powers and rights and duties as citizens. They have brought to light and started toward rectification our ineffective if not actually repressive methods of administration by legislative machinery. They have shown the inherent rights of the people in and to those material resources given value by their own work, and on which their own prosperity and perpetuity depend; and thereby they have warmed the spirit of unity among citizens and states. They have stirred patriotism more than any peaceful issue before, deeply as only bloody wars have done in the past. Incidentally, they are surely establishing the elective function as the primary power of representative government, and will no less surely establish the administrative function as correlative with those of legislative and judicative character.

ASSOCIATE MEMBERS OF AMERICAN SOCIETIES

By Professor EDWARD C. PICKERING

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TWO papers on "Foreign Associates of National Societies" were published in THE POPULAR SCIENCE MONTHLY, Vol. 73, p. 372, and Vol. 74, p. 80, in which the foreign membership of the seven great scientific societies of the world was discussed. It is the object of the present paper to make a similar study of the associate and honorary membership of the leading American societies, based on the latest printed lists. To avoid confusion, members paying fees will be called residents, those who live at a distance and pay no fees, associates, and foreigners, honorary members. All of the American members of the National Academy and the honorary members of the New York Academy, if Americans, will be included in the second class.

The oldest of American scientific societies is the American Philosophical Society held at Philadelphia for Promoting Useful Knowledge. It was founded in 1743, on the initiative of Franklin. Its membership consists of 165 residents, who live within thirty miles of Philadelphia, 224 associates and 113 honorary members. The number of persons elected each year is limited to fifteen Americans and five foreigners.

The American Academy of Arts and Sciences, founded in 1780, with its headquarters in Boston, is the second oldest scientific society. The numbers of residents (citizens of Massachusetts), associates and honorary members are 193, 87 and 63, and are limited to 200, 100 and 75, respectively.

The New York Academy of Sciences was founded in 1817. The numbers of residents, associates and honorary members are 468, 139 and 48, respectively. The numbers of the last two classes are limited to 200 and 50, respectively.

The National Academy of Sciences was founded in 1863, with its headquarters in Washington. Its membership consists of 113 associates and 45 honorary members. The number of the latter class is limited to 50.

Lists were next prepared of the associates and honorary members of these societies. Table I. contains a list of those Americans whose names appear on two or more of these lists. The successive columns give the name, place of birth, college, residence, specialty, date of birth and age at the time of election into each of the four societies. Place of birth and residence are indicated by states, or countries, except in the

TABLE I AMERICAN ASSOCIATES

Name	Birth	College	Residence	Specialty	Bir.	P	B	N	W
Abbe, C.	N. Y. City	A.B. City, N. Y.	Washington	Meteorol.	1838	33	46	...	41
Abbot, H. L.	Mass.	West Point	Cambridge	Engineer.	1831	31	*32*	...	41
Abbott, C. C.	N. J.	M.D. Penn.	Trenton	Zoology	1843	46	...	40	...
Allen, J. A.	Mass.	— Harvard	New York City	Zoology	1838	40	*35*	*36*	38
Ames, J. S.	Vermont	A.B. J. Hopkins	Baltimore	Physics	1864	41	...	...	45
Angell, J. B.	R. I.	A.B. Brown	Ann Arbor	Educ.	1829	60	39	...	...
Bailey, L. H.	Michigan	B.S. Michigan	Ithaca	Agric.	1858	38	42	...	...
Barnard, E. E.	Tennessee	— Vanderbilt	Williams Bay	Astron.	1857	46	35	...	...
Barus, C.	Cincinnati	— Columbia	Providence	Physics	1856	47	34	...	36
Becker, G. F.	N. Y. City	A.B. Harvard	Washington	Geology	1847	60	...	...	54
Bell, A. G.	Scotland	— London	Washington	Physics	1847	35	*30*	31	36
Billings, J. S.	Indiana	A.B. Miami	New York City	Physiol.	1838	49	43	...	45
Boas, F.	Germany	— Heidelberg	New York City	Anthrop.	1858	45	...	*30*	42
Bowditch, H. P.	Boston	A.B. Harvard	Jamaica Plain	Physiol.	1840	64	*32*	...	47
Branner, J. C.	Tennessee	B.S. Cornell	Stanford	Geology	1850	36	...	34	55
Brush, G. J.	Brooklyn	Ph.B. Yale	New Haven	Mineral.	1831	34	40	45	37
Campbell, D. H.	Michigan	Ph.M. Mich.	Stanford	Botany	1859	51	39	...	...
Campbell, W. W.	Ohio	B.S. Michigan	Mt. Hamilton	Astron.	1862	41	...	...	40
Cattell, J. McK.	Penn.	A.B. Lafayette	Garrison	Psychol.	1860	28	...	*34*	41
Chamberlin, T. C.	Illinois	A.B. Beloit	Chicago	Geology	1843	62	58	55	60
Chandler, C. F.	Mass.	— Harvard	New York City	Chem.	1836	39	...	29	38
Chittenden, R. H.	Connecticut	Ph.B. Yale	New Haven	Physiol.	1856	48	...	...	34
Choate, J. H.	Mass.	A.B. Harvard	New York City	Diplom.	1832	74	68	...	...
Clarke, F. W.	Boston	S.B. Harvard	Washington	Chemis.	1847	57	...	*29*	62
Comstock, C. B.	Mass.	West Point	New York City	Engineer.	1831	...	61	...	53
Coulter, J. M.	China	A.B. Dartmouth	Chicago	Botany	1851	...	41	...	58
Dall, W. H.	Boston	— Harvard	Washington	Zoology	1845	52	...	25	52
Dana, E. S.	Connecticut	A.B. Yale	New Haven	Mineral.	1849	47	44	36	35
Davenport, C. B.	Connecticut	B.S. Brooklyn	Spring Harbor	Zoology	1866	41	40	...	...
Davidson, G.	England	A.M. Mil. H. S.	San Francisco	Geodesy	1825	41	62	...	49
Davis, W. M.	Philadel.	S.B. Harvard	Cambridge	Geog.	1850	49	*34*	48	54
Dutton, C. E.	Connecticut	A.B. Yale	Englewood	Geology	1841	30	...	...	43
Emmons, S. F.	Boston	A.B. Harvard	Washington	Geology	1841	42	62	...	51
Farlow, W. G.	Boston	A.B. Harvard	Cambridge	Botany	1844	61	*30*	...	35
Flexner, S.	Kentucky	M.D. Louisville	New York City	Physiol.	1863	38	...	*43*	45
Frost, E. B.	Vermont	A.B. Dartmouth	Williams Bay	Astron.	1866	43	...	...	42
Furness, H. H.	Philadel.	A.B. Harvard	Wallingford	Author	1833	*47*	64	...	...
Gilbert, G. K.	New York	A.B. Rochester	Washington	Geodesy	1843	59	50	27	40
Gill, T. N.	N. Y. City	A.M. Columbia	Washington	Zoology	1837	30	...	21	36
Gooch, F. A.	Mass.	A.B. Harvard	New Haven	Chem.	1852	55	38	...	45
Goodale, G. L.	Maine	A.B. Amherst	Cambridge	Botany	1839	54	*35*	50	51
Hadley, A. T.	Connecticut	A.B. Yale	New Haven	Econom.	1856	46	46	...	...
Hague, A. D.	Boston	Ph.B. Yale	Washington	Geology	1840	63	64	...	45
Hale, G. E.	Chicago	B.S. Mass. Inst.	Pasadena	Astron.	1868	34	33	30	34
Hastings, C. S.	Clinton	Ph.B. Yale	New Haven	Physics	1849	57	...	...	40
Hilgard, E. W.	Bavaria	— Zurich	Berkeley	Geology	1833	...	71	...	39
Hill, G. W.	N. Y. City	A.B. Rutgers	West Nyack	Astron.	1838	65	*27*	60	36
Hillebrand, W. F.	Honolulu	— Cornell	Washington	Chem.	1853	53	...	...	55
Holden, E. S.	St. Louis	B.S. Washing.	West Point	Astron.	1846	51	39	...	39
Holmes, W. H.	Ohio	B.S. McNealy	Washington	Geology	1846	53	...	54	59
Howell, W. H.	Baltimore	A.B. J. Hopkins	Baltimore	Physiol.	1860	43	...	...	45
Jordan, D. S.	New York	M.S. Cornell	Stanford	Zoology	1851	54	...	25	...
Koenig, G. A.	Germany	M.E. Pol. Carl.	Houghton	Chem.	1844	30	...	32	...
Libbey, W.	N. Y. City	Princeton	Princeton	Geology	1855	42	...	39	...
Mahan, A. T.	New York	Naval Academy	New York City	History	1840	57	63	...	...
Mall, F. P.	Iowa	M.D. Michigan	Baltimore	Physiol.	1862	44	39	...	45
Mallett, J. W.	Ireland	Ph.D. Gott.	Charlottesville	Chem.	1832	53	51	44	...
Mark, E. L.	New York	A.B. Michigan	Cambridge	Zoology	1847	60	...	...	56
Mendenhall, T. C.	Ohio	———	Worcester	Physics	1841	58	*43*	...	46
Merriam, C. H.	N. Y. City	— Yale	Washington	Zoology	1855	47	...	19	47
Merriman, M.	Connecticut	Ph.B. Yale	New York City	Engineer.	1848	...	...	50	...
Michelson, A. A.	Germany	Naval Academy	Chicago	Physics	1852	50	33	...	36
Minot, C. S.	Boston	B.S. Mass. Inst.	Boston	Zoology	1852	44	*30*	26	45
Mitchell, S. W.	Philadel.	— Pennsylvania	Philadelphia	Physiol.	1829	*33*	36	...	36

Name	Birth	College	Residence	Specialty	Bir.	P	B	N	W
Moore, E. H.	Ohio	A.B. Yale	Chicago	Math.	1862	43	39	...	59
Morley, E. W.	New Jersey	A.B. Williams	Hartford	Chem.	1838	65	54	...	59
Morse, E. S.	Maine	— Harvard	Salem	Zoology	1838	57	*31*	26	38
Morse, H. N.	Vermont	A.B. Amherst	Baltimore	Chem.	1848	55	...	...	59
Monroe, C. E.	Mass.	S.B. Harvard	Washington	Chem.	1849	42	*42*	...	...
Nef, J. N.	Switzerland	A.B. Harvard	Chicago	Chem.	1862	...	46	...	42
Nichols, E. L.	England	B.S. Cornell	Ithaca	Physics	1854	50	47	...	47
Nichols, E. F.	Kansas	B.S. Kansas	Hanover	Physics	1869	37	...	...	39
Osborn, H. F.	Connecticut	A.B. Princeton	New York City	Zoology	1857	30	44	*34*	43
Peckham, S. F.	R. I.	— Brown	Brooklyn	Chem.	1839	58	...	37	...
Peirce, B. O.	Mass.	A.B. Harvard	Cambridge	Physics	1854	56	*30*	...	52
Peirce, C. S.	Mass.	A.B. Harvard	Milford	Logic	1839	...	*28*	...	37
Pickering, E. C.	Boston	S.B. Harvard	Cambridge	Astron.	1846	50	*21*	30	27
Prudden, T. M.	Connecticut	A.B. Yale	New York City	Physiol.	1849	...	55	*41*	52
Pumpelly, R.	New York	A.B. Yale	Newport	Geology	1837	37	*33*	31	35
Pupin, M. I.	Hungary	A.B. Columbia	Yonkers	Physics	1858	38	47	*32*	47
Putnam, F. W.	Mass.	S.B. Harvard	Cambridge	Anthrop.	1839	56	*26*	...	46
Remsen, I.	N. Y. City	A.B. City, N. Y.	Baltimore	Chem.	1846	33	*29*	30	36
Richards, T. W.	Philadel.	S.B. Harvard	Cambridge	Chem.	1868	34	*23*	...	31
Royce, J.	California	A.B. California	Cambridge	Philos.	1855	53	*36*	...	51
Sargent, C. S.	Boston	A.B. Harvard	Jamaica Plain	Botany	1841	41	*37*	...	54
Scott, W. B.	Cincinnati	A.B. Princeton	Princeton	Paleon.	1858	28	...	40	48
Scudder, S. H.	Boston	A.B. Williams	Cambridge	Zoology	1837	41	*31*	39	40
Sherwood, A.	Penn.	— Chicago	Portland, O.	Geology	1848	27	...	28	...
Smyth, C. H.	New York	Ph B. Columbia	Princeton	Geology	1866	42	...	29	...
Stephens, H. M.	Missouri	A.B Dickinson	Berkeley	Zoology	1868	29	32	...	...
Stevens, W. L.	Georgia	A.B. S Carol.	Lexington, Va.	Physics	1847	37	...	43	...
Thomson, E.	England	A.B. Phil. C. S.	Swampscott	Engineer	1853	*23*	*35*	...	54
Trelease, W.	New York	B.S. Cornell	St. Louis, Mo.	Botany	1857	46	35	...	45
Trowbridge, J.	Boston	S.B. Harvard	Cambridge	Physics	1843	53	*28*	34	35
Van Hise, C. R.	Wisconsin	B.M.E. Wis.	Madison	Geology	1857	52	...	43	45
Verill, A. E.	Maine	S.B. Harvard	New Haven	Zoology	1839	...	48	28	33
Walcott, C. D.	New York	———	Washington	Geology	1850	47	49	48	46
Webster, A. G.	Mass.	A.B. Harvard	Worcester	Physics	1863	43	*32*	...	40
Welch, W. H.	Connecticut	A.B. Yale	Baltimore	Physiol.	1850	46	51	...	45
White, A. D.	New York	A.B. Yale	Ithaca	Educat'n	1832	37	36	...	...
White, I. C.	West Va.	A.M. W. Virg.	Morgantown	Geology	1848	30	...	26	...
Whitman, C. O.	Maine	B.A. Bowdoin	Chicago	Zoology	1842	57	*48*	56	53
Wood, H. C.	Philadel.	M.D. Penn.	Philadelphia	Physiol.	1841	...	46	25	38
Woodward, R. S.	Michigan	C.E. Mich.	Washington	Astron.	1849	53	47	...	47
Wright, A. W.	Connecticut	A.B. Yale	New Haven	Physics	1836	60	...	40	45

case of a few large cities. The four societies are indicated by the initials of the headquarters of each, P, B, N and W. Resident membership is indicated by italics.

The discussion of Table I. is complicated by the fact that several men were elected as residents, and later moving to another state, were made associates. Three men were made honorary members of the New York Academy. In all these cases, the first election is that entered in the table. Twenty-one men, including the three just mentioned, are members of all four societies, and will be designated below as of class A.

From the second column, it appears that the birthplaces are distributed as follows: Massachusetts, 22; New York, 18; Connecticut, 10; Pennsylvania, 7; Maine and Ohio, 4 each; Michigan and Vermont, 3 each; foreigners, 13, of whom 5 came from Great Britain, and 4 from Germany. The only cities furnishing more than one member are

Boston, 11; New York, 8; Philadelphia, 5; Cincinnati, 2. Of 105, 41 come from New England and 26 from the Middle States, making nearly two thirds, in all. Of class A, 6 were born in New York, including 3 in New York City; 5 in Massachusetts, 4 of them in Boston; 3 in Maine, and 2 in Connecticut.

A grouping of the colleges where these men got their education led to unexpected results, as follows: Harvard College, 12; Lawrence Scientific School, 12; Yale College, 9; Sheffield Scientific School, 6; Cornell, Michigan and common schools, 5 each; Columbia and Princeton, 3 each. Nine colleges educated 2 each. Harvard and Yale, therefore, educated 39, or rather more than a third of the whole. The numbers of living graduates in the four institutions, Harvard College, Lawrence Scientific School, Yale College and Sheffield Scientific School, are about 12,000, 1,200, 8,000 and 4,000. Accordingly, the proportion is 1 out of 1,000, 100, 900 and 700, for the four institutions, respectively. The average numbers of societies are 2.5, 3.3, 2.6 and 2.5, respectively. Evidently the greatest possible number is 4.0, and the least, 2.0. The number of graduates of the other institutions is too small to determine averages with accuracy. The average 3.3 for the Lawrence Scientific School is only surpassed by the Massachusetts Institute of Technology, 2 members, average 4.0, and Williams College, 2 members, average, 3.5. Of class A, 5 are graduates of the Lawrence School, 2 of Yale College and 2 as just stated of the Massachusetts Institute of Technology.

The present residence of these men according to cities is as follows: Boston, New York and Washington, 15 each; New Haven, 8; Baltimore and Chicago, 6 each; Princeton, 4; Berkeley, Ithaca and Stanford, 3 each; Philadelphia, Williams Bay and Worcester, 2 each. The suburbs of each city are included in it. Thus, Boston includes Cambridge, and represents, practically, Harvard College. Of class A, 6 are residents of Boston, 3 of New York, 3 of Washington, 2 of Chicago and 2 of New Haven. While birthplaces indicate conditions of about sixty years ago, and colleges forty years ago, residences indicate nearly present conditions.

The other columns of Table I. are better discussed in connection with the corresponding columns of Table II. The latter gives a list of the foreigners who are honorary members of two or more of these societies. The successive columns give the name, residence, specialty, year of birth, age at time of election into each of the four societies and number of the seven national societies of which each man is a member. The numbers in the last column are taken from the article already mentioned.

In Table II. the residences are distributed as follows: Germany, 16, of which 8 are in Berlin and 3 in Leipzig; England, 15, of which 7 are in London and 4 in Cambridge; France, 4, all in Paris; Holland,

3; Austria, 2, both in Vienna; Edinburgh, Palermo, Berne and Stockholm, 1 each. Eight men are members of all four societies, and of them five are residents of England.

TABLE II

HONORARY MEMBERS

Name	Residence	Specialty	Birth	P	B	N	W	No.
Auwers, A.	Berlin	Astronomy	1838	...	42	60	45	7
Baeyer, A. von	Munich	Chemistry	1835	75	49	...	63	7
Bornet, E.	Paris	Botany	1828	...	65	...	73	3
Broegger, W. C.	Christiania	Mineralogy	1851	48	...	53	52	4
Bryce, J.	Washington	Diplomacy	1838	57	55	...	...	...
Darwin, G. H.	Cambridge	Geography	1845	...	53	54	59	4
Delitsch, F.	Berlin	Archæology	1850	54	52	...	...	...
DeVries, H.	Amsterdam	Agriculture	1848	55	...	56	56	3
Dewar, J.	Cambridge	Physics	1842	57	...	60	65	...
Diels, H.	Berlin	Philology	1848	61	59	...	...	...
Engler, A.	Berlin	Botany	1844	62	57	...	...	...
Fischer, E.	Berlin	Chemistry	1852	57	56	49	52	7
Geikie, A.	Surrey	Mineralogy	1835	45	65	41	66	6
Geikie, J.	Edinburgh	Geology	1839	37	...	62	...	...
Gill, D.	London	Astronomy	1843	67	67	...	55	6
Haeckel, E.	Jena	Zoology	1834	51	...	60	...	2
Hann, J.	Vienna	Meteorology	1839	...	63	60	...	3
Hoff, J. H. van't	Berlin	Chemistry	1852	52	43	...	44	7
Hooker, J. D.	Sunningdale	Botany	1817	52	49	62	66	6
Kapteyn, J. C.	Groningen	Astronomy	1851	56	...	...	56	...
Klein, F.	Göttingen	Geometry	1849	...	55	47	49	6
Kohlrausch, F.	Marburg	Physics	1840	69	60	...	...	5
Kronecker, H.	Berne	Medicine	1839	...	62	...	62	2
Lankester, E. R.	London	Zoology	1847	56	55	51	56	5
Larmor, J.	Cambridge	Physics	1857	...	46	...	51	...
Lister, J.	London	Medicine	1827	70	66	...	71	4
Lockyer, J. N.	Kensington	Astronomy	1836	38	...	44	...	3
Lorentz, H. A.	Leyden	Physics	1853	53	...	...	53	5
Maspero, G. C. C.	Paris	Philology	1846	45	39	...	...	...
Nansen, F.	Lysaker	Geography	1861	36	...	37	...	3
Ostwald, W.	Leipzig	Chemistry	1853	...	52	55	53	4
Penck, A. F. K.	Berlin	Geography	1858	50	...	40	51	...
Pfeffer, W. F.	Leipzig	Botany	1845	64	52	53	58	6
Picard, E.	Paris	Geometry	1856	54	47	47	47	5
Poincaré, H.	Paris	Geometry	1854	45	47	46	44	7
Ramsay, W.	London	Chemistry	1852	47	...	49	52	7
Rayleigh, J. W.	Essex	Physics	1842	44	46	57	56	7
Retzius, N. G.	Stockholm	Zoology	1842	...	65	...	57	6
Roscoe, H. E.	Leatherhead	Chemistry	1833	70	57	54	...	3
Stoney, G. J.	London	Physics	1826	76	...	78	...	...
Strasburger, E.	Bonn	Botany	1844	...	48	64	54	5
Suess, E.	Vienna	Mineralogy	1831	55	...	...	67	7
Thomson, J. J.	Cambridge	Physics	1856	47	46	40	47	3
Unwin, W. C.	London	Engineering	1838	52	62	...	...	...
Waldeyer, W.	Berlin	Mineralogy	1836	68	...	...	73	...
Wundt, W.	Leipzig	Physiology	1832	63	...	72	77	...

Considering now the 105 Americans in Table I., and the 46 foreigners in Table II., we find that the four societies, as already stated, contain 224, 87, 142 and 113 associates, and 113, 63, 48 and 45 honorary members. The numbers of these included in Table I. are 96, 70, 48 and 82, and in Table II., 36, 31, 27 and 32.

Sciences are not easily grouped, since many are closely connected. An approximate grouping of Table I. gives: geology, 20; zoology, 15; astronomy, 15; physics, 14; chemistry, 13; physiology, 10; botany, 7; miscellaneous, 11. Class A gives: geology, 7; zoology, 6; astronomy, 3; physics, 3; chemistry, 1; botany, 1. Table II. gives: astronomy, 9; physics, 7; chemistry, 7; geology, 6; botany, 5; zoology, 3; physiology, 3; miscellaneous, 6. The large number of geologists and zoologists in Table I., and especially in class A, is remarkable, and the reversion of this condition in Table II. Of the 20 geologists in Table I. there is only 1 mineralogist, while in Table II., of 6 geologists, there are 4 mineralogists. Table I. contains but 1 mathematician, while Table II. contains 4.

Important conclusions may be drawn from the order of election, but the discussion is beset with unusual difficulties. A society which chose members who were later elected into all the other societies would display remarkable skill. In class A, the number of members first elected by the four societies is 2, 10, 8 and 1, respectively. But it is much easier to become a resident than an associate, and 13 members were elected as residents of the American Academy, and 2 of the New York Academy. Omitting these, the numbers become 3, 0, 13 and 5. Accordingly, the New York Academy appears to have shown extraordinary skill in selecting early, men of such ability that later they were chosen by all the other societies. This result is confirmed by the eight foreigners who are members of all four societies. Four of these were first elected by the New York Academy, in two cases before they were elected by either of the seven leading European societies. The last column of Table II. shows that 32 men are members both of the European and American societies; of these, 23 were first elected by a European society, 6 by an American Society and 3 in the same year by both. Of the 9 in the last two classes, 6 were chosen first by the American Academy.

The numbers elected in the different societies, during the last ten years, differ greatly. Thus, for associates, we have from 1901 to 1905, 26, 15, 0 and 20, and for 1906 to 1910, 17, 1, 1 and 13. For honorary members no such differences occur, the numbers for 1901 to 1905 being 8, 11, 9 and 12, and for 1906 to 1910, 11, 5, 3 and 9. Only 2 honorary members were elected into the National Academy before 1896, both in 1883. In the New York Academy, 11 associates were elected in 1876. Of course all of these numbers relate only to the selected lists contained in Tables I. and II.

THE PALEONTOLOGIC RECORD

ONTOGENY: A STUDY OF THE VALUE OF YOUNG FEATURES IN DETERMINING PHYLOGENY

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IN this paper I want to study what value is to be given to the principle that ontogeny is a brief recapitulation of phylogeny, when it comes to the concrete determination of the ancestry of a given genus. For the purpose three types have been studied carefully and several more for confirmations, the principal study being between the young and adult of the pig, cat and man, the differences being noted to see if they suggested the forms considered ancestral.

First let us consider the skull of a six weeks' pig in comparison with that of the adult, the two having been drawn to the same length. The first and most marked variation is in the brain case, that of the young being relatively vastly larger. The same is especially true of the sense capsules of the ear and eye. The later growth is much greater in those parts of the skull designated as facial, or having to do with the jaws and their supports. Then there is a change in the axis of the skull, this being due to the growth of the maxilla region, and lastly where there is any cellular bone or bone spaces they are developed in later life. This factor is especially well shown in the development of the elephant skull and in ruminants. It is coincident with high crests and marked protuberances.

While most of the features have been indicated in the pig, the same comparison in the cat reveals the same excessive development of the brain case and sense organs, the same weakness of the jaws and change in the axial relations, and this may be further confirmed in looking at the contrast between a three-year-old child's skull and that of an adult.

The conclusions then to be drawn from this hasty comparison of the two skulls are, first, that the shape of the skull in the young shows the excessive development of the brain and sense capsules, so that the appearance is not that of a primitive animal, but exactly the contrary, the appearance which the genus would assume were its mental or nervous development carried to a much higher degree than is the case. The embryonic development of the brain and sense organs is pushed far toward the beginning, and is matured, as far as size is concerned, the earliest of any of the systems. The skull is first an envelope for the brain and sense organs and is therefore profoundly modified by this embryonic peculiarity, and *the younger the individual the less like the adult or ancestor the skull is shaped.*

Secondly, the change of axis is not in the ancestral direction, the excessive weak condition of the jaws being again an embryonic adaptation and not an ancestral one.

Lastly, in the development of cancellous tissue is a condition which more nearly approximates the phylogenetic development, but here even the use of young features is deceptive, for it is seldom that this cellular bone is developed in the immediate ancestor but is rather found in several genera back, being usually an accompaniment of the development of the heavy facial portion of the skull. So much for form.

Turning to the dentition. The milk set of the pig and those of the adult are drawn side by side, and it is seen that while the front teeth of the young approximate those of the adult, the comparison is between the complicated premolar and molar sets. Briefly, of the four premolars, if all present, in the young (and often but three are developed) the two in front resemble the premolars to succeed them in the permanent set, while the two rear milk premolars resemble the permanent molars, the last milk premolar being especially like the last molar. This granted, the interest centers around whether the pattern of the milk teeth is such as to indicate the ancestry. A glance at the pig and its young will show that while the detail is not exactly the same in young and old, yet they are so alike that no one would identify a single milk molar as *Hyotherium* or any other suine genus, but would have to put it in the genus *Sus*. Taking other cases among the Ungulata, the history of the naming of the Miocene genera of horses gives a good example. There are, according to Gidley, four genera, *Hyohippus, Parahippus, Merychippus* and *Protohippus;* of these, three were founded on young teeth, *i. e.,* the first three named. When it was recognized that they were young teeth, they were by Cope assigned to *Protohippus,* but when the adult teeth were found it was clear that the distinctive features of these young teeth were the distinctive features of the adult. For the genus *Merychippus* there is a difference in that the young teeth are not cemented, while the adult are. That is ancestral. In analyzing the descriptions of several genera of horses usually some feature can be found in the milk tooth which is ancestral.

In the Carnivora there is the carnassial tooth which is specialized; in the upper jaw it is the third milk premolar and the fourth in the adult; in the lower jaw it is the fourth milk premolar, and the first molar of the adult. Thus it is clear that it is a different dental follicle which forms the young and the adult carnassial. In the case of the dog the permanent and milk carnassials are approximately alike, but in the case of the cat the inner lobe or protocone occupies a very different place in the young from that of the adult, a position characteristic of none of the Felidæ and suggests some of the apparently unrelated Creodonts.

In the matter of the succession of teeth the follicles which form the last two—the milk premolars—form teeth in the first set of a totally different and usually more advanced character than the teeth to be formed from the same follicles in the permanent set. As a general thing then the conclusion would be that the milk teeth tend to have the same characters as mark the permanent set, but when they vary they often retain characters of the phylogenetically ancestral form. Weber adds that the later the succession the less the difference between the milk and permanent sets.

Turning to the limbs, there are again several distinctly ontogenetic characters, which are by no means ancestral. First, the formation of epiphyses, so that a bone ossifies from three or more centers. This is purely an ontogenetic adaptation and has no phylogenetic significance. Then the articular ends of all the limb bones are greatly enlarged as compared with adults. This again is not phylogenetic but an adaptation, the joints and their ligaments being early approximated to their permanent conditions. Then the length of limbs seems to be effected as an embryonic adaptation. First take the case of man born with disproportionately short arms and legs. The legs have been interpreted as representing a phylogenetic condition, but the same rule does not apply to the arms which were ancestrally long. This feature of short limbs is also characteristic of carnivora and I feel that it is an embryonic adaptation; certainly the ancestral limb can not be deduced from the young condition. Quite the reverse of conditions obtains among the Ungulata where the young at birth have disproportionately long limbs, which with equal certainty does not represent any ancestral condition recapitulated, for the ancestral limb in ancestral forms is shorter. Again, I believe the anomalous legs are adaptations to either the necessity for speed on the part of the young, or for height to reach the teats, suckling being while the parent is standing.

In the cases of the reduction of digits, greater portions of the reduced digits are usually found in the young animals than in the adults, but in the case of the entire loss of a digit it is also lacking in the young and embryo.

The general conclusion of the whole matter would then be that the young give us very little which is not deceptive in reconstructing ancestral forms. In certain cases, namely in the teeth and in reduction of digits, confirmatory points may be obtained, but these must be used with care, the valuable constructive evidence being rather found in adult skeletons, and in morphological comparisons. While allowing that many stages are recapitulated in the development of an individual, the vast number of adaptations impressed on the young to be used after birth, *make their skeletons specialized even from birth,* and *such differences as exist are seldom reminiscent.*

PALEONTOLOGY AND ONTOGENY

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ONTOGENY, or the life history of the individual, is commonly interpreted by zoologists as its embryology, the later stages of development, from infancy to old age, being deemed of little or no importance. This was the case fifty years ago; this is largely the case to-day. From the days when Agassiz first called the attention of zoologists to their one-sided attack of the problem of ontogeny, and urged them to pay attention to the important post-embryonic stages, down to our own time, students of recent animals have for the most part been content to follow the beaten path. They have left to the paleozoologist the study of the later stages in the life history of the individual, and the latter's endeavors in this direction have developed the science of zoontogeny as to-day understood. There was, perhaps, a natural cause for this separation, in the fact that the student of soft tissues finds few changes which he deems worthy of attention, between the embryo and the adult; whereas the student of hard structures generally sees an abundance of such changes. This is especially true of invertebrates, more particularly of such as build external hard structures in which successive additions are marked by the lines of growth. Vertebrates, and invertebrates without permanent hard parts, such as the crustacea, require series of individuals showing the successive steps in development. But mollusks, brachiopods and corals show, by their incremental lines, the steps in the life history during the post-embryonic period, so that one perfect individual suffices to present these later stages in development.

It is not infrequently urged that the hard parts of invertebrates, especially the shells of mollusks, are not reliable indices of ontogenetic development, since they represent only the integument, which is subject to ready modification under the influence of the environment. Such an argument is based on a total ignorance of the relation of the shell or other hard structure to the soft parts of the animal. The paleontologist is convinced that the hard parts of animals are the best indices of its development, since they record in a permanent form all the minute modifications which are not even recognizable in the soft parts. More than this, I believe that shells, those of mollusks at any rate, furnish us with a record of changes wholly independent of the environment, and referable entirely to an inherited impulse towards progressive modification, along definitely determinable lines. I am well aware that I am not expressing the opinion of all paleontologists in this statement, and that this view, moreover, is strongly opposed by some of our ablest European conchologists. But here again I contend that this difference

of opinion is due to a difference of method. When the student of shells directs his attention chiefly to adult characters, this definitely directed variation, independent of environment, is not recognized by him. But no one can study the details of shell ontogeny, especially in the earlier stages, without quickly realizing that ontogenetic development is orthogenetic, and that the inherited impulse towards determinate modifications is the most powerful controlling factor of the animal's life history.

So far as invertebrates are concerned, the study of post-embryonic development was first seriously undertaken by the immortal Hyatt, in his work on the ammonites. To be sure, others before him—notably d'Orbigny—noticed that a distinct series of changes was recognizable in the shell of ammonites, but no one before Hyatt actually employed this method. He himself once told me that when, in the early sixties, he first realized the importance of this method of study when actually applied to shelled organisms, and its value as a guide in phylogeny, it seemed so marvelously simple that he felt sure that the method and its application must be fully understood by all working naturalists. "But," he added, "I soon found that I practically stood alone, and I have spent my life since in the endeavor to convert them to my point of view."

This misunderstanding, on the part of many zoologists, of the ontogenetic method has given rise to their false attitude towards the doctrine of the recapitulation of ancestral characters. This subject will be adequately treated by some of my successors, but I can not forbear to anticipate them to the extent of pointing out this fact: When the embryologist seeks for proof or disproof of this concept in the enormously condensed record of the stages between the ovum and birth, he is bound to be grievously disappointed; for this record, necessarily modified by eliminations, can only furnish general resemblances of the embryo to earlier types, and can not be said to actually recapitulate the life history of the entire race. When, however, the student of post-embryonic ontogeny compares the youthful stages of an individual with the adult of immediately preceding species of the same genetic series, the fact of recapitulation becomes at once apparent.

The post-embryonic life history of an individual falls readily into stages, of which four major ones have been recognized and named, chiefly by Hyatt. These are: (1) the infant or nepionic stage; (2) the adolescent or neanic stage; (3) the adult or ephebic stage, and (4) the senile or gerontic stage, followed by death. These *onto-stages,* as they may be called, are further divided into substages, designated by the prefixes *ana, meta* and *para,* and they may be observed in the ontogeny of all individuals. Moreover, in closely related members of one genetic group, the duration of these stages and substages is approximately uniform. Change in form, however, may vary greatly, and have

no necessary relation to the onto-stages, even if they coincide with them. We have thus a second group of stages, which we may designate *form stages,* or morphic stages, and there will be required distinct designations in each case. The best method of naming these stages is to refer them to the adult ancestral type which they represent.

Thus, in all species of the gastropod shell *Fusus,* the earliest morphic stages are a close recapitulation of the adult of *Fusus porrectus* of the Eocenic. These stages may therefore be called the *F. porrectus* stage. It may be continued for a considerable period of the early life history, covering several onto-stages, or it may be condensed into a short portion of one stage or substage, in accelerated individuals.

It is of considerable importance that onto-stages and morphic stages should be discriminated, so I will introduce another illustration.

In the Miocenic of the Atlantic coast we have the gastropod genus Fulgur well represented. *Fulgur fusiformis* is normally characterized, in the adult, by the possession of a pronounced flat shoulder, which is separated from the body of the shell by an angulation carrying rounded tubercles. Some of the more specialized individuals lose the angulation and tubercles in the last whorl and become rounded. Thus, while normally the species is tuberculated in the ephebic onto-stages, specialized individuals acquire a new morphic stage through the loss of ornamentation. This morphic stage is prophetic of the normal adult of *Fulgur maximum,* and hence may be called the *F. maximum* stage. *F. maximum* itself has in its nepionic onto-stage the characters of adult *F. fusiformis;* hence it may be designated the *F. fusiformis* stage. Some individuals acquire a new stage, namely, a spinous stage, characteristic of the adult of *F. carica.* In the type designated as *F. tritonis,* the nepionic stage is characterized by a fusiformis morphic stage, the neanic largely by the maximum stage, though some of the later neanic stages may actually acquire the *carica* stage. In less specialized individuals the maximum stage may continue into the early ephebic in more specialized ones it ceases early in the neanic, the *carica* stage taking its place. Finally, *Fulgur carica* is characterized by the elimination of the maximum morphic stage, so that the neanic as well as the ephebic onto-stages are characterized by the spines of the *carica* stage, which may even begin in the late nepionic.

In the foregoing, the different morphic stages are shown to be telescoped with the onto-stages, appearing either earlier and earlier in the ontogeny of successive individuals, through the operation of the law of acceleration or tachygenesis; or later and later, through the operation of the complementary law of retardation or bradygenesis. These laws are, of course, only applicable to an orthogenetic series, but in such a series they are competent to produce, by interaction, all conceivable combinations of characters.

The paleontologist, more than any other naturalist, is concerned with the product of these interactions, and to him, oftener than to others, has come the question, Are these results species? and, if so, what are the criteria for the separation of species? The student of hard structures appreciates the difficulty of drawing sharp lines, and one of his most trying tasks is to satisfy the idiosyncrasies of his colleagues in the making of species, subspecies, varieties, etc. The student of hard parts finds transitional forms the rule, and he dare not grind them to powder under his heel with the remark credited to Stimpson, that "that is the proper way to dispose of those damned transitional forms."

The philosophic paleontologist recognizes more readily than any one else the truth of the dictum that nature knows only individuals, and that species are special creations, called into being by the fiat of the naturalist. He is concerned not so much with the origin of species as with the origin of individuals; and while he makes use of the artificial divisions called species, and sometimes finds his chief joy in multiplying and subdividing them, he still recognizes their non-existence, and turns to individuals. He may, perhaps, prefer to speak of mutations, meaning individuals, nevertheless.

But individuals are complex entities, and the paleontologist can not investigate their genesis before he has thoroughly investigated the origin of the parts composing it. As Professor Osborn has said, the paleozoologist is concerned primarily with the origin of structures. He alone is able to trace their development, for he is present at their birth, he follows their whole history, and will be present also at their extinction, for the paleontologist alone is immortal.

PALEONTOLOGY AND THE RECAPITULATION THEORY

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I

BATHER once said that "If the embryologists had not forestalled them, the paleontologists would have had to invent the theory of recapitulation." This may be considered as a fair sample of the attitude of at least the Hyatt school of paleontologists toward the theory. It is doubtful if any paleontologist could be found who wholly rejects it.

In violent contrast with the more or less complete acceptance of the theory by paleontologists, is the attitude of many embryologists and zoologists. Montgomery and Hurst have perhaps put the case against recapitulation more strongly than any one else. The former says, for example,

> The method is wrong in principle, to compare an adult stage of one organism with an immature stage of another.

And again:

> Therefore we can only conclude that the embryogeny does not furnish any recapitulation of the phylogeny, not even a recapitulation marred at occasional points by secondary changes.

Hurst is even more emphatic. He says:

> The ontogeny is not an epitome of the phylogeny, is not even a modified or "falsified" epitome, is not a record, either perfect or imperfect of past history, is not a recapitulation of evolution.

It would seem as though two statements could scarcely be more flatly contradictory than those of Bather and Hurst, just quoted. Nevertheless, I venture to make the assertion that both parties to the recapitulation controversy are right, for the simple reason that they are not talking about the same thing. Grabau has called attention to this, by implication, in one of his papers on gastropods. He states that the recapitulation theory has been placed in an evil light by the habit of embryologists of comparing *embryonic* stages with the adults of existing representatives of primitive types, and that they have commonly neglected to compare the *epembryonic* stages with the adults of geologically older species. In other words, paleontologists have usually dealt, in their comparisons, with epembryonic stages, and embryologists with embryonic stages.

There arises here a question of definition: does the biogenetic law mean that the *ontogeny* is a recapitulation of the phylogeny, or does it mean that the *embryogeny* is a recapitulation of the phylogeny? If we take the general consensus of opinion, we shall find for the former definition; and if we take the words of Haeckel, whose statement of the law is the one usually quoted, we shall again find for the former definition.

It is certainly true, at any rate, that the epembryonic stages may and do show recapitulation, even when the embryonic stages do not, or when the embryogeny is so obscured by secondary adaptations as to be untrustworthy. There are many reasons why adaptations should occur in intra-uterine or larval life to obscure the ancestral record. These have often been stated and discussed, and I shall pass them with this mere mention. That the record of remote ancestors, contained in the embryogeny, may be lost or obscured, while the record of nearer ancestors, contained in the epembryogeny, is still clear and convincing, is my contention; and I hold that this contention is substantiated by the studies of a host of paleobiologists.

While contrasting the views of biologists and paleobiologists, I do not wish to create the impression that all of the former have turned against the theory of recapitulation. Several recent studies of the development of extant forms seem to afford very satisfactory evidence that the theory is not wholly rejected in the house of its fathers. Of

these I may mention the very interesting papers by Griggs on juvenile kelps, Zeleny on the development and regeneration of serpulids, and Eigenmann on the blind vertebrates of North America.

Griggs especially criticizes the views of such critics of recapitulation as His, who holds that the reason why ontogeny seems to recapitulate phylogeny is because the developing organism must from physiological necessity pass from less to more complex stages, more or less resembling ancestral forms; and the views of Morgan, who holds that only embryonic stages of ancestors are repeated. This is the so-called "Repetition Theory." To both of these critics Griggs objects that they confuse physiology and morphology. "The recapitulation theory," he says, "has nothing to do with physiology; it is purely a matter of morphology."

On the first point, that the developmental stages are merely the physiologically necessary steps in the development of the adult organism, the conclusions of Eigenmann and Zeleny are of especial interest. Eigenmann shows that in the blind fish, *Amblyopsis,* the development of the foundations of the eye is normal, and is phylogenic, while the stages beyond the foundations are direct. Zeleny concludes that the ontogenesis of the opercula of serpulids is phylogenic, and recapitulates ancestral characters; but the regeneratory development of the organ is direct, and may be very different from the ontogenetic development. We may ask, therefore, if development takes a certain course only because that is the physiologically necessary way in which the individual or the organ must develop, why should a condition of perfect blindness, with almost total loss of all the eye structures, be attained only by the round-about method of first developing the foundations of a normal eye? Why, again, if there is any physiologically necessary course of development, should the serpulid be able to regenerate the opercula in a manner entirely different from their ontogenesis?

Hatschek, Hurst, Montgomery and others maintain that, if two individuals differ in the adult, they must also differ in the egg, and consequently must be different at all stages between. From this thesis they draw the conclusion that organisms can not recapitulate adult ancestral characters, because any change in the adult stage of an individual, causing it to be different from its parents, involves a change in the entire ontogeny—"the entire row of cells" from the egg to the adult. That there is some sort of change in the entire row of cells we grant; but that this change necessarily affects the *morphology* of the individual or of its organs, up to the adult stage, we do not grant. We have here again a confusion of morphology and physiology. The cell energies may indeed be changed; but unless a change in the cell energies inevitably necessitates a change in the morphology of all the cells or of all the organs which they compose, the argument of Montgomery proves nothing.

If inheritance were perfect, the individual would take exactly the same course in development as its ancestors. That it does not do this in all cases is a more remarkable fact than that in so many cases it follows the ancestral mode of development so closely. This loss of inheritance is due to a progressive condensation of ontogeny, or as it is commonly called, acceleration. Most embryologists misconceive the law of acceleration, limiting it to the omission of characters or stages. With the classic formulation of the law by Hyatt we are all familiar. According to Hyatt, acceleration involves not only omission, but condensation without omission, through the earlier inheritance of characters acquired in the adult or adolescent stages of life. By the unequal acceleration of characters an overlapping, or telescoping, as Grabau calls it, may be introduced. It follows, therefore, that acceleration may be by *elimination,* by *condensation* without change in the order of appearance of characters, and by condensation with change in the order of appearance, or *telescoping.* As conceived by the paleobiologist, the law of acceleration is an explanation of recapitulation, as well as an explanation of the failure to recapitulate.

Another factor in inheritance is retardation, so named by Cope. By the operation of this law, characters that appear late in the ontogeny may disappear in the descendents, because development terminates before the given characters are reached. In this way the ontogeny may be shortened and simplified, and many ancestral characters may be lost entirely. The result of the continued operation of retardation is retrogression, since the loss of the characters of nearer ancestors, with the continued repetition in early ontogeny of the characters of remote ancestors, must eventually cause the species to resemble the remote, rather than the nearer, ancestors.

II

Of the numerous cases adduced by paleontologists, in which there is clear evidence of recapitulation, I shall mention a few only.

Probably the best known examples of recapitulation are those made known by the researches of Hyatt, Branco, Würtenburger, Buckman, Smith and others among the Cephalopoda. It is shown that Ammonites pass through a goniatite stage, and that, as phrased by Zitttel, "The inner whorls of an ammonite constantly resemble in form, ornament and suture line the adult condition of some previously existing genus or other." The nautilus grows at first straight or orthoceraform, then arched or cyrtoceraform, and finally at the close of the first volution of the shell, becomes close coiled. The impressed zone appears in ancient nautiloidea in the neanic stage, where the whorls first come into contact, and is indeed a *result* of contact. In modern nautilus, and in Mesozoic and Tertiary nautilus the impressed zone appears in

the nepionic stage, *before the whorls come into contact.* It has been carried back in the ontogeny by acceleration. Smith concludes from a study of the development and phylogeny of *Placenticeras,* an Upper Cretaceous ammonoid, that "the development of *Placenticeras* shows that it is possible, in spite of dogmatic assertions to the contrary, to decipher the race history of an animal in its individual ontogeny."

Among the Gastropoda, Grabau and Burnett Smith have pointed out numerous beautiful cases of recapitulation. In *Fusus* and its allies, the higher forms quite constantly resemble in their earlier stages the adults of ancestral forms. Even in profoundly modified gerontic types, the young resemble the ancestors. Smith has brought to light in *Athleta* (*Volutilithes*) of the Eocene, an almost perfect example of even and regular acceleration, with its correlative, the recapitulation in the young of the Upper Eocene forms of the adult characters of the Lower Eocene forms. The stages passed through by this group of shells are, beginning with the earliest, a *smooth, curved rib, cancellated, spiny* and sometimes a *senile* stage. In the ancestral species (*A. limopsis*) the curved rib stage comes in at the close of the fourth whorl, whereas in the Upper Eocene form (*A. petrosa*), this stage comes in at the beginning of the third whorl.

Among the Pelecypoda the classic researches of Jackson are familiar to all. He shows that the modern *Pecten* passes through, in its ontogeny, a series of stages resembling adult *Rhombopteria, Pterinopecten* and *Aviculopecten,* and that the geologic order of these genera is the same as the ontogenetic order in *Pecten.* In such monomyarian genera as *Ostrea,* the initial shell, or prodissoconch, is dimyarian, and resembles the primitive *Nucula.* Again, in various more or less widely separated genera, the condition of complete cemented fixation has produced the ostreaform shape. Each one of these genera, however, except where the modification of shape due to fixation appears very early in ontogeny, recapitulates the adult characters of its respective ancestor. The examples of this are *Mulleria,* a member of the Unionidæ—like *Anodon* in the young; *Hinnites,* a member of the Pectinacea—like *Pecten* in the young; Spondylus, another member of the Pectinacea—like *Pecten* in the young.

Beecher's various studies of the Brachiopoda not only brought out the fact that the initial shell or protegulum of the brachiopod is remarkably similar to the most primitive known Lower Cambrian brachiopods, but have supplied in addition numerous other remarkable examples of recapitulation. One of the most striking of these is the case of the Terebratellidæ. In both the boreal and austral subfamilies a very complete series of genera correspond to the ontogenetic stages of the terminal or highest genera. Another interesting case is that of *Orbiculoidea.* This discoid shell has at first a straight hinge like *Iphidea.*

It next resembles *Obolella,* then at a later stage it is like *Schizocrania,* and finally adult growth brings in the characters of *Orbiculoidea.* Raymond has shown the remarkable similarity of the neanic stage of *Spirifer mucronatus* to the adult *S. crispus* of the Niagara. Shimer and Grabau found in the upper Hamilton of Thedford, Ontario, a variety of *Spirifer mucronatus* that is very mucronate in the young and not at all so in the adult. The derivation of this form from *S. mucronatus* is beyond question. I have pointed out a precisely similar case in *Platystrophia acutilirata* var. *senex.* This variety, which occurs in the upper Whitewater beds of Indiana and Ohio, has a hinge angle of nearly 90° in the adult. In the young, however, the outlines of the shell are exactly like the typical *P. acutilirata,* from which it is beyond any question descended. Greene has shown that *Chonetes granulifer* of the Carboniferous is, in the neanic stage, like the Devonian *Chonetes,* and that the hinge-spines come in at a considerably earlier stage in the Carboniferous than in the Devonian and Silurian forms, showing the acceleration of this character.

In the Bryozoa I have pointed out the fact that the colony behaves as an individual, and like an individual recapitulates in its ontogeny (astogeny) ancestral characters. This is beautifully shown in *Fenestella,* in which the earlier zoœcia are strikingly like the adult zoœcia of the Cyclostomata. The adolescent zoœcia of Devonian *Fenestella* are similar to the adult zoœcia of Niagara forms. Lang has brought together numerous cases of recapitulation among Jurassic and Cretaceous *Stomatopora* and *Proboscina.* The method of dichotomy in the earlier portions of the colony is constantly more like the normal dichotomy of ancestral species.

In graptolites the remarkable researches of Ruedemann clearly indicate that the graptolite colony recapitulates ancestral characters, the proximal thecæ being similar to ancestral adult thecæ. He says:

> **The rhabdosomes in toto and their parts, the branches, seem also to pass through stages which suggest phylogenetically preceding forms.**

Among the trilobites the studies of Beecher, Walcott and Matthew are classic. Beecher has shown that there is a common larval form, the protaspis, and that in higher genera characters appear in the protaspis that are known only in the adults of more primitive genera. For example, the " main features of the cephalon in the simple protaspis forms of *Solenopleura, Liostracus* and *Ptychoparia* are retained to maturity in such genera as *Carausia* and *Acontheus.*" Larval *Sao* has characters that occur in the adult of *Ctenocephalus.* The larval stages of *Dalmanites* and *Proetus* have characters that appear only in the adult of ancient genera.

Among the corals Beecher and Girty show that such genera as *Favosites* have early stages that suggest *Aulopora.* Lang, in a recent

paper, records very interesting cases of recapitulation in the genus *Parasmilia* of the Cretaceous. Bernard concludes that the coral colony, like the graptolite colony and the bryozoan colony, behaves as an individual.

In the echinoderms the likeness of the stem ossicles and the development of the anal plate of *Antedon,* to Paleozoic and Mesozoic forms has become one of the stock illustrations of recapitulation. Jackson has found interesting examples of recapitulation in the development of the ambulacral and inter-ambulacral plates of echinoids. Miss Smith has shown that the young *Pentremites* is exactly similar in form to the adult *Codaster.* This is an extremely interesting case, for Bather has independently, and from quite different data, come to the conclusion that *Pentremites* is derived from *Codaster.*

The idea of recapitulation has been one of the most fertile in the whole realm of biology, and its usefulness to the paleobiologist has been almost incalculable. But while there can be no doubt that recapitulation is a fact, the paleontologist should observe all due care not to assume too much for it. That there are various sorts of adaptations, arising at all stages of life, and that these may greatly obscure the ancestral record, is a fact too well known to require more than mention. There is also always acceleration, sometimes affecting different characters very unequally; and there may be retardation. All of these factors complicate the record of ontogeny. Nevertheless, after all of these have been taken duly into consideration, the parallel between ontogeny and phylogeny remains a powerful aid to investigation for the paleontologist.

VERTEBRATE PALEONTOLOGY AND THE EVIDENCES FOR RECAPITULATION

By L. HUSSAKOF

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AFTER the careful papers of Professors Loomis and Lull in which the doctrine of recapitulation was so fully set forth from the standpoint of vertebrate paleontology, I can perhaps do no better than devote part of the time allotted me to showing how certain leading vertebrate paleontologists have viewed this question. Then I will cite one or two illustrations of this principle drawn from among the lower vertebrates.

Passing over the period of pre-Darwinian paleontology—the paleontology of Cuvier, Owen and Louis Agassiz—we come to the time of Leidy, who, as Professor Osborn has recently shown,[1] was one of the first,

[1] In his address on "Darwin and Paleontology" printed in "Fifty Years of Darwinism." Centennial addresses in honor of Charles Darwin, New York, 1909, p. 209.

if not the first, to bring the fruits of paleontology to the support of evolution. But Leidy, as far as a hasty search through his writings could reveal, nowhere expressly advocated the doctrine of recapitulation. Indeed, he gave but little attention to the philosophical bearings of paleontology, generally partly because of temperament and partly because in those pioneer days material to serve as a basis for generalization was still scanty.

Gaudry, one of the first European paleontologists to champion the cause of evolution,[2] likewise did not specially advocate the doctrine of recapitulation. An examination of his "Philosophie Paleontologique" fails to reveal any definite belief in this doctrine.

Huxley, as far as I can gather from his papers and essays, believed in this doctrine, though with certain implied reservations as to its general applicability. In his presidential address to the Geological Society of London on "Paleontology and the Doctrine of Evolution" delivered in 1870, we find some interesting comment on the significance of the splints of the living horse, which he regards as indicative of the presence of three complete digits in the horse ancestor. But Huxley was never an out-and-out advocate of the biogenetic law.

Cope and Marsh, as we all know, were staunch upholders of evolution; and Cope, at least, was also a staunch upholder of the doctrine of recapitulation. In his "Primary Factors of Organic Evolution," his last contribution to philosophical paleontology, he devotes considerable space to proving this doctrine. He says:[3]

> The representatives of each class passed through the stages which are permanent in the classes below them in the series.

And he backs up this proposition with evidence derived from the ontogeny and phylogeny of batrachia, the antlers of deer and the blood trunks of vertebrates generally. For all that, Cope recognized the justice of certain criticisms which had been brought against the doctrine of recapitulation and urged caution in its application.

An example or two of recapitulation may now be cited from the field of the lower vertebrates.

The mode of development of the teeth in *Neoceratodus* has sometimes been adduced as an illustration of recapitulation. It is well known that the Devonic dipnoans (*e. g., Dipterus*) had teeth composed of rows of denticles, those in each row being more or less fused at their bases. During the history of the dipnoans since the Devonic period, the separate denticles have merged more and more until in *Ceratodus* and the living *Neoceratodus,* the rows of denticles are, in

[2] According to a letter from Darwin to Gaudry dated January 21, 1868. "The Life and Letters of Charles Darwin," edited by his son Francis Darwin, New York, 1899, Vol. II., p. 269.

[3] "Primary Factors of Organic Evolution," Chicago, 1896, p. 195.

the adult, replaced by almost smooth ridges. Now, Semon in his beautiful studies on the development of *Neoceratodus*[4] has shown that the teeth of this fish at one stage in ontogeny, are represented by rows of denticles even more discrete than the denticles in the Devonic *Dipterus;* then the denticles gradually merge at their bases, the separate cusps, however, still showing—a stage comparable with the Carboniferous *Ctenodus;* then they merge still more and assume the ridge-like form seen in the adult *Neoceratodus.*

Another example: In many sharks the alimentary canal is longer in the embryo than in the adult, the anal opening being situated near the posterior end of the trunk. From such cases one is inclined to believe that in the ancestral sharks this must have been the condition in the adult form; that is to say, the anal opening probably was near the posterior termination of the trunk. We may therefore ask: are there any early fossil sharks which show such a condition? Recently Professor Dean has described[5] a remarkable specimen of *Cladoselache* from the Upper Devonic of Ohio which seems to indicate such a condition. In this specimen remnants of both kidneys are preserved. They extend in the posterior half of the fish and by their direction indicate that they were drawn together, toward their external opening, not far from the posterior termination of the trunk. This shows that the anal opening in this ancestral shark was very much as in the early shark embryo to-day.

In conclusion perhaps I may venture to make one other point in regard to this question. A vast amount of skepticism concerning the doctrine of recapitulation is to be found in the literature of to-day; and if we study the reasons for this skepticism we find that it is in some measure justified. It is clearly established that among vertebrates as well as among invertebrates there are many examples of structures appearing during embryonic growth which are identical with structures found in the adult of some remote ancestor. But when we reflect on the amount of adaptation which any embryo has undergone in its long evolutional history; when we remember how palingenetic characters are on every hand overlaid by cenogenetic ones; who will say that recapitulation is a principle of general application, or that it is safe to draw conclusions from all embryos concerning their long extinct ancestors? Who will believe that a bony fish which runs through its embryonic development in a few days repeats its ancestral history, when we see at every stage of its ontogeny how it has been adaptively modified for this and for that special need? Only when series of related forms have certain onto-

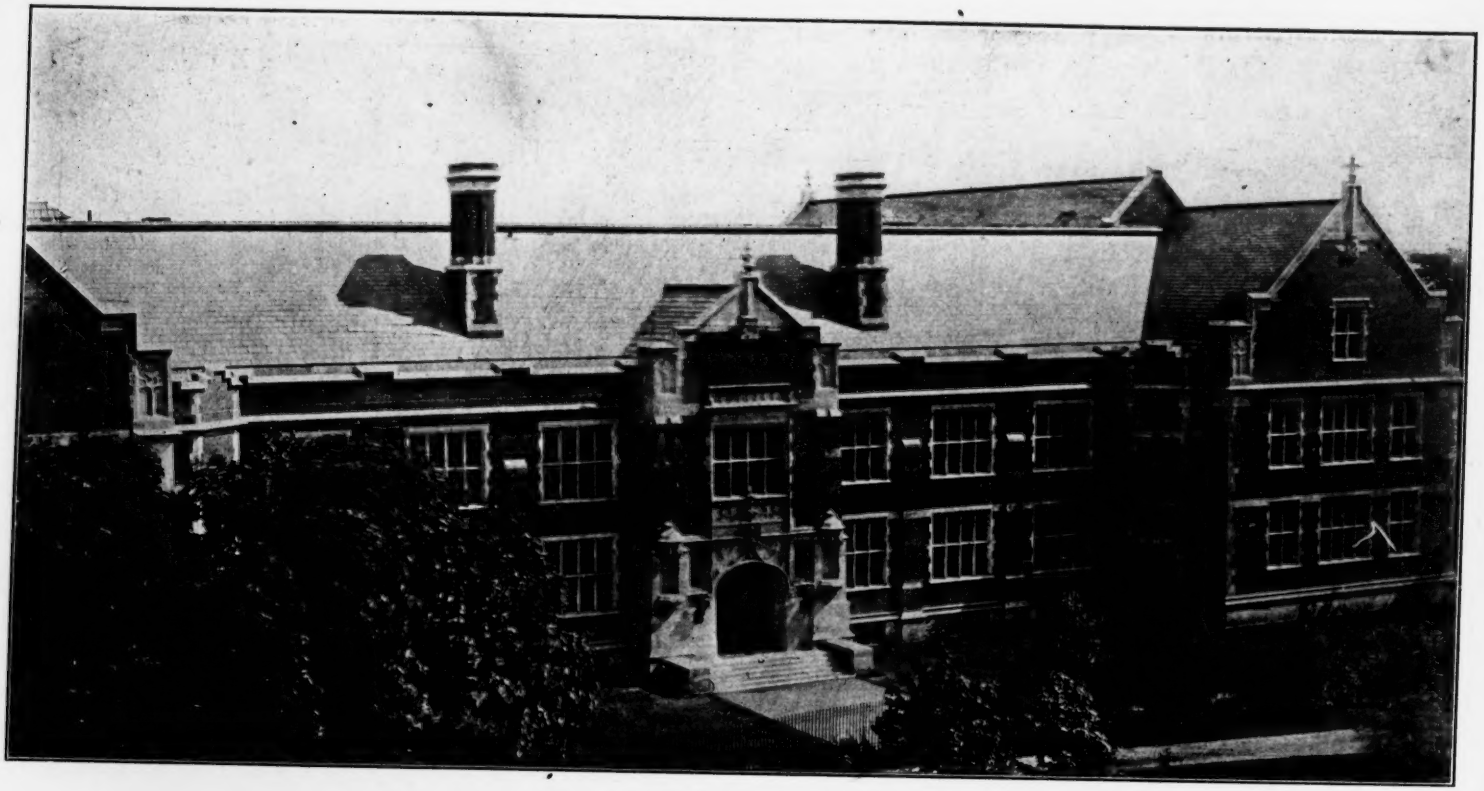
[4] "Die Zahnentwickelung des *Ceratodus forsteri*," "Zool. Forsch. in Austral. u. Malay. Archipel.," 1899, pp. 115–135, pls. xviii–xx.

[5] *Mem. Amer. Mus. Nat. Hist.*, Vol. IX., p. 232.

genetic stages in common are we justified in inferring that their racial ancestor may have had such characters in the adult state. But it should never be lost sight of that this inference is only a provisional hypothesis which may or may not be verified when the paleontologic record is more complete. It is no surprise that the efforts of some earnest paleontologists have been discredited in some quarters, especially among zoologists. Some of them have invoked recapitulation as a sort of magic spell by which they can conjure up ancestral forms from almost any embryonic series, forgetting the limitations of this doctrine. As far as the attitude of vertebrate paleontologists is concerned, their view has been aptly summarized by Professor Charles Depéret in his book "Les Transformations du Monde Animal" and I can do no better than close with a quotation from him:

> If we appeal to paleontology, it must be recognized that this hypothesis [recapitulation] is by no means verified. There do exist here and there certain fossil genera, which all their lives have retained certain youthful characteristics apparent in their living descendants; but when it comes to reconstructing whole series chronologically continuous, grave contradictions are met with, and it is only in the groups of the mammals and perhaps of the reptiles [and, we may add, fishes] that it becomes possible to present a few examples sufficiently demonstrative.[6]

[6] "Les Transformations du Monde Animal," Paris, 1907, p. 117.



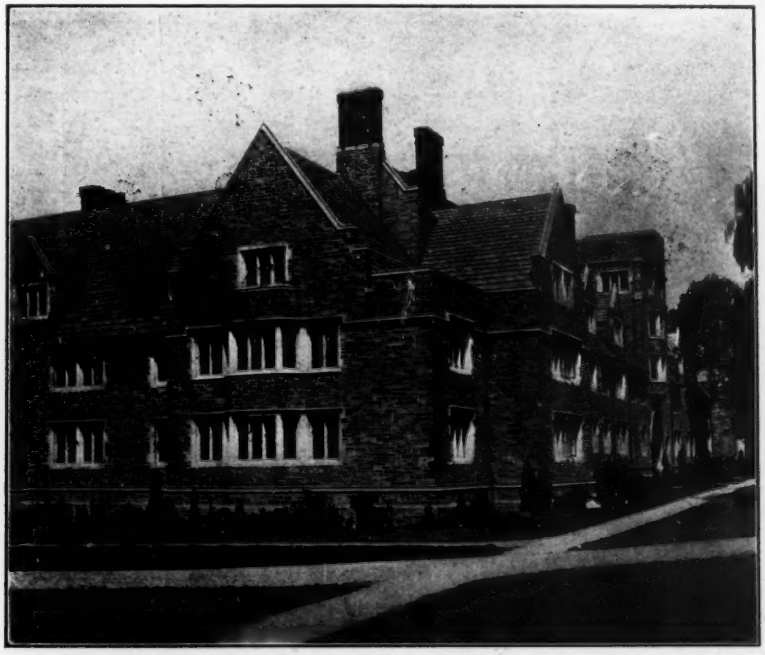
THE PALMER PHYSICAL LABORATORY.

THE PROGRESS OF SCIENCE

THE SCIENTIFIC LABORATORIES OF PRINCETON UNIVERSITY

THE colleges first established in this country prior to the revolution, apart from the two in Virginia, have all become great universities within the past forty years. Harvard, Yale, Columbia and Pennsylvania have preceded Princeton in this development, and for a period it was doubtful whether Princeton should be ranked among the universities or among the colleges. When, on the occasion of its sesquicentennial celebration in 1896, the official name of the College of New Jersey was changed to Princeton University, it was not so much a measure of what had been accomplished as a promise of things hoped for but unseen. The prophecy is now, however, in course of fulfilment. Princeton, it is true, has no professional schools, except its departments of civil and electrical engineering. A law school was once established, but it lasted only two years. No school of medicine is in contemplation, though the first two years of a medical course could be given to advantage. The theological seminary in the village has supplied a large proportion of the students registered in the graduate department, but it has no official connection with the university and is too narrowly denominational to be regarded as a graduate school of theology.

In most of our universities, however, the professional schools scarcely form an integral part of the institution and the graduate school is the place in which university and research work is accomplished. Such work has been



HOLDER HALL, a dormitory erected by Mrs. Sage.

GUYOT HALL.

gradually developed at Princeton in the course of the past few years, and there is likely to be now a mutation which will place the university among those where productive scholarship and creative research are most cultivated. The difficulties in regard to the graduate school which have been so widely exploited are in fact rather trivial and are now fairly solved, as the university has not only money for a residence hall but also for the men who are the real university. The Swan bequest of $300,000, the gift of $500,000 from Mr. Proctor, once withdrawn but now renewed, and the Wyman bequest, amounting probably to over $2,000,000, are all for the graduate school and give it a free endowment scarcely equaled at any other university.

Like all our institutions Princeton has spent relatively too much money on buildings and too little on men. But the money has come freely and the architectural setting at Princeton will appeal to the alumni and to the general public as the worthy exterior manifestation of a great university. It is also true that Princeton has done much for its men. In the preceptorial system it has undertaken to extend the personal contact between teacher and student which is one of the most marked advantages in the teaching of the sciences, to the departments not having laboratories, and has brought to Princeton some fifty selected men of the younger generation with the rank of assistant professors. The method adopted may be open to certain criticisms, but this group of men has added greatly to the strength of the university. In the meanwhile the laboratory departments have been developed both by buildings and by men. The department of physics has been made one of the strongest in the country and one of our leading zoologists has been called as head of the department of biology.

The buildings recently erected for physics and for natural science are shown in the accompanying illustrations. In both of them the academic Gothic style has been well adapted to laboratory construction. The Palmer

Physical Laboratory, erected and equipped by Mr. S. S. Palmer, and endowed with $200,000 by Mr. D. B. Jones and Mr. T. D. Jones, is admirably adapted for work in physics and electrical engineering. The three floors have an area of approximately two acres for the work of instruction and research, and every need in the way of appliances and apparatus is provided.

Guyot Hall, completed last year at a cost of $425,000, is divided about equally between biology and geology, giving the latter science probably the best provision in the country. The building contains over a hundred rooms, including a large museum. Biology has in addition a separate building as a vivarium for the study of living plants and animals. The aquaria have both sea and fresh water, and there is provision for insects, amphibians, reptiles, birds and mammals. Near by is a pond and stream where animals may be kept under natural conditions.

Princeton offers opportunities for study and research in the natural and exact sciences which are in some ways unique. The situation in the country, but within easy reach of New York and Philadelphia, offers many advantages. With its peculiar attractions, Princeton takes its place with the great universities so closely lining the eastern seaboard—Harvard, Yale, Columbia, Princeton, Pennsylvania and the Johns Hopkins.

COMPARATIVE PSYCHOLOGY IN AMERICA

THE last number of the *Zeitschrift für Psychologie* devotes twenty-two pages to a review of the recent literature of comparative psychology. This review covers more or less adequately the material for the years 1907, 1908 and 1909. Twenty-eight articles are noted of which nineteen are by American authors, one by an Englishman and the remaining eight by Germans.

This review emphasizes the fact that comparative psychology is largely an American branch of science. It began, in so far as the study of higher animal forms in this country is concerned, in 1898, with the classical work of Thorndike on "Animal Intelligence," which was followed three years later by his study of the "Mental Life of the Monkeys." Shortly afterwards small comparative laboratories were added to the already existing experimental laboratories of Clark, Harvard and Chicago, and in these the great bulk of the animal work has since been done. Recently a fairly adequate animal-behavior laboratory has been added to the psychological department of the Johns Hopkins University. It has been an interesting fact in the development of this field that the work has not been confined wholly to specially developed technical laboratories. Several important pieces of work have appeared under psychological auspices from the universities of Cornell, Illinois and Stanford and from the zoological laboratories of the universities of Chicago, Harvard and Johns Hopkins, and of the Carnegie Institution.

The work in this country has been characterized by systematic and long-continued studies of certain groups of problems; while that in foreign countries has been more sporadic. The work of Pfangst on "Der kluge Hans," which has been translated by Mr. Carl Rahn and that of Katz and Révész on the light sense of the chick are the two conspicuous examples of systematic and careful work in Germany. In the United States work has been centered around three problems: (1) the general method of learning (problem boxes, mazes, etc.) which gives acquaintance with the animal's instinctive capacities and prepares the way for a study of (2) imitation (and the effect of tuition) and (3) the determination of the delicacy and completeness of its sense-organ equipment.

The first problem received the greatest amount of attention during the first

few years. We now know something at least of the learning process, to mention mammals alone, of several of the monkeys (Thorndike, Kinneman, Watson, Haggerty); dogs and cats (Thorndike, Hamilton); raccoons (Davis and Cole); the rat (Small, Watson, Berry, Richardson); the dancing mouse (Yerkes); the guinea-pig (Allen) and the grey squirrel (Yoakum). Other forms have not been neglected, and we have to-day as a result of the ten years' work a fairly respectable body of knowledge on the learning methods and capacities of animal forms ranging from the amœba to man. This work has shown that even the lowest organisms possess plasticity. Jennings has been chiefly responsible for challenging the continental idea (Loeb, Bethe, Beer, Bohn and others) that the behavior of the invertebrates is of the fixed and non-plastic type.

The second problem, that of imitation, has been largely studied. Unfortunately the work in this direction has been characterized by a marked difference in experimental results. Thorndike (dogs, cats, monkeys) and Watson (monkeys) have been convinced by their results that learning by imitation is not an important function in animal adjustment. Haggerty (monkeys), Porter (birds) and Berry (rat, and manx cat) reach opposite conclusions. Haggerty's recent work on the chimpanzee and ourang shows clearly that imitation of a complex character is present in the anthropoid apes. There is still room for doubt in the case of other animal forms.

Careful work on the sensory equipment of animals is only just beginning. The American Psychological Association has appointed a committee for the determination of standard methods of testing vision in animals. The appearance of this report will probably lead to renewed interest in this problem. It ought to have the effect of making the work of the different investigators directly comparable and to lead to safe conclusions concerning the phylogenetic development of sense organ processes.

In conclusion, the renewed interest in field observation may be mentioned. The establishment of laboratories for the study of animal behavior at first drew interest away from field work. Recently animal psychologists have been forced to admit partially the truth of the claims of Wesley Mills, John Burroughs, Hobhouse and Morgan, viz., that animal experimentation ought not to be carried out under too rigorous and unnatural conditions. Studies in the field in the last ten years have been made by the Peckhams (insects), Newman (amphibia) and Watson (birds). Interesting possibilities in field observation are offered in studies of the beaver, the prairie dog and lizards.

SCIENTIFIC ITEMS

WE regret to record the deaths of Dr. Johann Gottfried Galle, the eminent German astronomer, at the age of ninety-eight years, and of the Rev. Robert Harley, F.R.S., an English congregational clergyman, known for his contributions to mathematics and symbolic logic, at the age of eighty-three years.

AT a meeting of the Berlin Academy of Sciences on June 30, commemorative addresses were made on Friedrich Kohlrausch, by Professor Rubens; on Hans Landolt, by Professor van't Hoff, and on Robert Koch, by Professor Rubner.—On October 2 the unveiling of the statue of Johann Gregor Mendel will take place at Gregor-Mendel-Platze in Altbrünn.—A tablet in memory of Richard Hakluyt, the navigator, was unveiled in Bristol Cathedral on July 7, the address being made by Sir Clements Markham.